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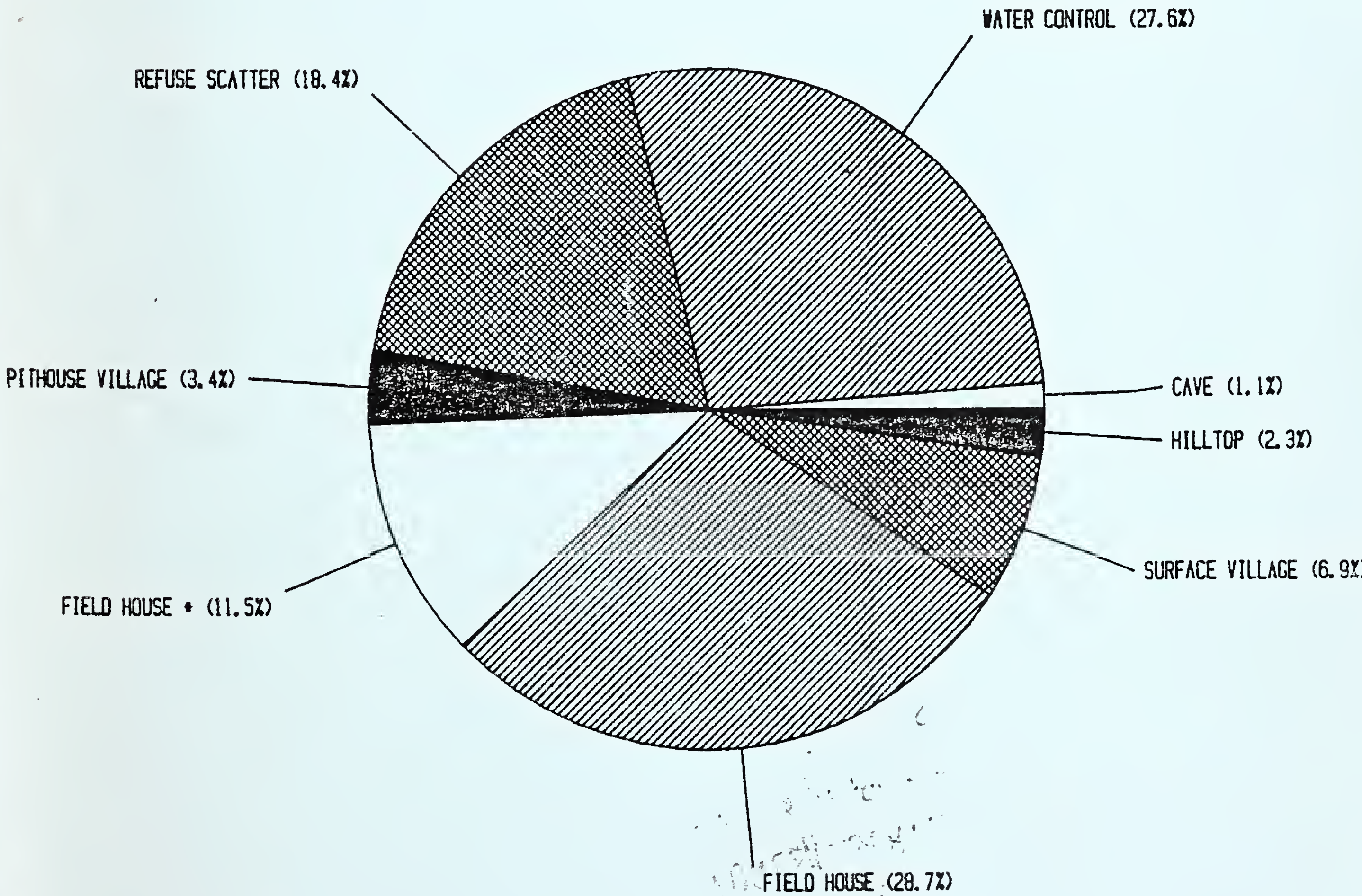
# Cultural Resources Document

## Theory and Model Building: Refining Survey Strategies for Locating Prehistoric Heritage Resources



# E R R A T A

On page 63 it is stated that lithic scatter sites are no longer being recorded on the Kaibab National Forest. Variations of the statement also appear on pages 65, 119, 123, and 126. The management policy of recording lithic scatters is being followed by the Kaibab National Forest, a fact substantiated by review of Kaibab cultural resources reports.

# THEORY AND MODEL BUILDING: REFINING SURVEY STRATEGIES FOR LOCATING PREHISTORIC HERITAGE RESOURCES

## Trial Formulations for Southwestern Forests

Edited By

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# PREFACE

This volume represents another collaborative effort among archeologists from the academic and federal communities, brought together by the USDA Forest Service to pursue ideas of mutual interest. As with previous endeavors (Green and Plog 1983, Winter 1983), we have attempted to 1) address a topic of importance to the management of cultural resources and to current archeological thought, 2) make a contribution to archeological scholarship, and 3) publish the results in a timely manner. We remain convinced that joint efforts by archeologists from the federal and academic communities make far better contributions toward the solution of cultural resource management problems than either group could by itself.

Predictive modeling in archeology is a method for estimating the likelihood of the occurrence of cultural resource sites on the landscape for which the model was developed. It is not, as some suppose, a technique to predict precisely where sites are located in the absence of any empirical field data. Point prediction of that magnitude is not possible currently, nor can it be developed in the very near future. Surveys are still needed to actually locate sites, but models can be designed to give managers a sound basis for deciding where their limited survey dollars should be spent. This volume lays the groundwork for building such models and concludes that there is a reasonable chance of success if theory development, model building and model testing are carried out concurrently and with adequate support. We are pleased to have been involved in the effort and thank our conference colleagues who worked so hard to make this contribution possible.

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# ACKNOWLEDGEMENTS

The support base for a conference does much to insure its success yet receives little recognition. We trust those whose names appear here will understand our gratitude for their fine service. Financial support was a joint effort by the Washington and Regional Directors of Recreation. We thank Roy Feuchter, Ed Stone, and Paul Weingart, respectively for providing the needed funds to allow the conference. The University of New Mexico's D. H. Lawrence Ranch provided the facilities for the conference. Al Bearce and his staff were most hospitable from food preparation to concern for the little problems that always arise with using an unfamiliar facility. Landon Smith is singled out for his dedication to preparation of the data bases prior to the conference. Personnel on the Carson National Forest were most helpful with duplicating, use of their Tektronics digitizer, and numerous small details. The help of Jon Young, Tom Bruce, and Kathie Gibbs is especially appreciated. At the Regional Office, Dave Gillio offered many valuable editorial suggestions, Fred McGee assisted with data preparation, Joann Mares, Sally Terry, and Debra Smith typed the manuscript. We thank them all.

# INTRODUCTION

Dee F. Green

The need for refining archeological survey strategies has been apparent for some years. During the 1970s a few scholars have approached the problems (Burton, et. al. 1979; Plog, Plog, and Wait 1978; Schiffer, Klinger, and House 1978) but there is little evidence that the implications of their studies are being widely applied by cultural resource managers in the 1980s. Questions of cost effectiveness, survey levels, survey intensity, and other issues remain. In the 1980s "predictive modeling" has become the operative phrase. This may refer to a variety of techniques and ideas (Kohler 1983) most of which are concerned with inventing ways to deal with the problem of why cultural sites are located where they are. In the Southwest this question was first addressed systematically by the Southwestern Anthropological Research Group (SARG) (Euler and Gumerman 1978, Gumerman 1971, 1972). Their joint research effort beginning in the early 1970s has had moderate success but has been hampered by the difficulties of bringing a diverse group of scholars together on a sustained basis to pursue the research.

During the past few years a wide variety of uncoordinated efforts under the rubric of predictive modeling have been pursued around the country (Kohler 1983 references and papers presented at the 48th Annual Meeting of the Society for American Archeology, Pittsburg, April 1983). These models share a common failure to show concern with the development of any theoretical underpinnings which would explain why the models developed, did or did not work. Their strengths consist of a wide variety of techniques which have been tested using a variety of archeological data bases. During the past decade, then, a fits and spurts approach has left us with the tantalizing notion that predictive modeling ought to work but unsure as to how well; and unsure as to how many models might be needed for any given space.

While the archeological community has been pursuing various modeling approaches, land managers have been asking for better and more cost effective ways of doing the archeological job. Moves by the current administration in Washington, DC to cut federal spending have spurred the need for increasing cost effectiveness. Thus, a clear need to pursue the idea of understanding site locating behavior on the part of human beings has been increasing.

As a response to that need, the Southwestern Region invited a number of scholars to attend a meeting on predictive modeling during the fall of 1982. These scholars were drawn from the academic community as well as the Forest Service including National, Regional, and Forest levels. The meeting resulted in a paper (Cordell, DeBloois, Green, and Tainter 1983) outlining a four stage plan for the development of predictive models and the generation of a theory of land use for National Forest system lands in the Southwestern Region. The paper calls for four stages: 1. planning, 2. development, 3. testing, and 4. evaluation to be spread over four years. This volume is a result of implementing the first or planning stage.

During the planning stage our goal has been to examine model building and theory building in order to assess the likelihood that they could be successfully pursued. In formulating the organization of the conference we deliberately decided to pursue the theory and model building together so that greater feedback between the two efforts could occur. It seemed unwise to develop theory without models for testing the theory and it seemed equally unwise to attempt model building without a theoretical basis for explaining why a model might or might not work. The latter is especially important given a desire to apply models over extensive landscapes.

The organization of this volume reflects this dual purpose of the conference by reporting the model and theory building efforts. We did not anticipate that the results of the conference would provide any more than a working formulation of either a theory or of a model(s). Rather, our expectations were that trial models could be formulated which would need refinement and testing. We also expected that the theory building would only set parameters for what needs to be done. As the following chapters demonstrate these expectations were essentially fulfilled. We do not have any complete models, nor do we have comprehensive theory to explain any models, but we do have a groundwork for pursuing both efforts with a reasonable expectation of success.

# THEORY BUILDING

## INTRODUCTION AND BACKGROUND

Joseph A. Tainter

Early in the planning stages for the conference it was felt that a dual approach to predictive modeling should be employed. The elements of this approach are: 1) empirical, data-based modeling, and 2) development of theories of land use. The rationale and methods underlying the databased modeling are discussed in the introduction to that section. The present introduction will discuss the objectives and rationale behind the theory building effort, and other matters pertinent to that effort.

### OBJECTIVE

The objective of this effort is to develop a theoretical basis for understanding and predicting the locations of past activities on the Southwestern National Forests. A theoretical basis is one that is explanatory, abstract, and generalizeable. Such frameworks, to be useful, should not be restricted in their applicability to individual cases, but should be able to account for a large number of specific instances. Hence, the frameworks developed in the next few papers are highly abstract, in order to be as broadly applicable as possible.

### RATIONALE

There are a number of reasons why a substantial theoretical basis should be incorporated into any effort in predictive modeling. These reasons are as follows.

1) To have confidence in any models which emerge, we need to know <u>why</u> the behavior we predict patterns as <u>it</u> does.

2) We need some framework for assessing what went wrong if the models do not work.

3) We require a framework that will allow us to <u>confidently</u> transfer a model developed in <u>one area</u> to some other area, or to modify it if indicated.

4) Explanation and understanding are our goals as social scientists. The application of scientific knowledge to management purposes should not be based on any less stringent goals, or we will serve management poorly.

Good resource management, in any field, must be based upon good science. Conversely good resource management can rarely emerge from poor or incomplete science. The development of predictive models, without a concomitant understanding of why they work, would be inadequate science, and would lead inevitably to poor management.

### DEVELOPMENT

Given the extensive information already available about the environmental settings of Southwestern archeological sites, we felt that this data base should not be ignored in our efforts, but rather that model building and theory formation should proceed in a lock-step fashion, with continuous feedback.

The development of theory relating to activity location is something that the archeological profession has undertaken only within the last few years. The first major, systematic efforts in this area were perhaps those of the Southwestern Anthropological Research Group, which in the early 1970s developed a cooperative research program based on the question "Why are sites located where they are?" (Plog and Hill 1971).

And although the archeological profession has a strong interest in that question, no uniformly acceptable answer to it has emerged. As a result, when cultural resource managers began to develop an interest in predictive modeling, it rapidly became clear that this was a sphere in which many archeologists had grave reservations, and in which many more had simply a great deal of collective uncertainty. That uncertainty, and the skepticism which accompanies it, are not likely to dissipate soon, and will never disappear without substantial, collective efforts such as that which resulted in this volume. The development of general, widely-applicable theories of land use is an essential part of reducing that skepticism, as is the formation of actual predictive models that are comprehensive and reliable. At the same time, a further element in overcoming professional resistance to predictive models must be research devoted to the question of when are predictive models appropriate, and when they are not.

It should not be expected that the papers herein will resolve the issue, although they should contribute toward resolution. The effort detailed in the following papers is by no means a comprehensive theory of land use. It is a first step in that direction. It makes no attempt to account for all patterns observeable in presently available data. What it does do is to give a better theoretical underpinning to modeling efforts than is typical for such attempts.

Explicit theory construction relating to activity location, although of perennial interest to the profession, has not received commensurate attention. As a result, the present effort breaks much new ground. This being so, our goals for these initial formulations are modest. We begin with relatively simple theoretical formulations that are broad and general, with the expectation that, as the overall Forest Service predictive modeling program develops, so also will the complexity, sophistication, and explanatory power of its theoretical base.

## ISSUES

Predictive modeling raises various questions that must someday be dealt with, even if they cannot be resolved through the present effort. The theoretical framework of archeology offers a perspective on some of these issues that would be worthwhile to discuss at this point.

1) If one of the goals of a predictive modeling program is to attempt cost savings in archeological survey through excluding unlikely areas, then there will inevitably be a major temptation to key survey intensity to the <u>density</u> of archeological remains that are anticipated. For example, if it is expected that a region will contain large residential sites clustered in a small portion of the area, and small debris scatters from resource gathering scattered throughout the remainder, it will be tempting to reduce survey costs by investigating only the small land area where the largest sites are expected.

Such an approach must be avoided, for it is injurious both to the resource as well as to the future of archeological science. This kind of selectivity not only injects a substantial element of bias into our data base, it is unjustifiable within the current orientation of the discipline. Archeology today is in large part concerned with questions of subsistence, settlement, and land use, that is, with human participation in ecological systems. We seek to know the nature of past human adaptive systems, why these systems were the way they were, and what factors caused them to change. To understand subsistence economies, it is necessary to have information concerning the locations in the environment from which resources were extracted, and the methods by which this was accomplished. Resource extraction activities often leave behind an archeological record that is light and ephemeral (Tainter 1979, 1983), and highly scattered. The nature of past adaptive systems cannot be understood if we exclude such scattered, low density remains from our data base, and from active management. Thus, the present ecological orientation within the discipline <u>requires</u> the recovery and management of data on foraging behavior. At the same time, our goal of preserving archeological resources for the future obligates us to ensure, as far as possible, that the resources preserved are not a skewed, highly biased sample (Tainter and Gillio 1980: 149-150; Tainter and Lucas 1983).

Cost is, of course, always a consideration, and there is no doubt that the recovery of information about dispersed archeological sites is more costly than for clustered remains. Ultimately it may prove desireable to develop integrated combinations of predictive models and random sampling schemes, to ensure unbiased site inventories. Any approach which systematically excludes entire segments of the prehistoric use of the Forests is unacceptable.

2) There are elements of uncertainty regarding how specific the theoretical underpinning of our predictive models needs to be. Over the span of occupation of the Forests, the <u>sum</u> of the locations used by specific kinds of adaptive systems will lead to a general picture of those portions of the Forests where cultural remains of <u>any</u> population may be expected to occur. For predicting survey areas, and survey costs, this general picture of where <u>any</u> activity (or any activity requiring survey identification) might have occurred is the relevant piece of management information. The theoretical basis which assists in generating such information can range from the general to the specific. Very general theoretical formulations might be restricted, for example, to predicting only gross differences in use of vegetation zones, or variation in intensity of use with increasing elevation. At the opposite extreme, very specific theoretical formulations might predict such things as differences in portions of the Forests used by Early vs. Middle Archaic populations. At which point along the scale from general to specific should we focus our efforts?

The most general formulations are not satisfactory. They would contribute very little to our overall understanding of use of the Forests, and from the management perspective, would not greatly refine our ability to focus on areas of high site likelihood. The opposite extreme is probably both unnecessary for our current purposes, and beyond the current state of our knowledge. Some middle ground in the specificity of our theoretical formulations would seem preferable from both a scientific and a management perspective. Our approach is not to focus on specific, tem-

porally restricted adaptive systems, but rather on generalized types of activities. The activities we have delineated are as follows:

- hunting and gathering
- agricultural
- settlement
- specialized (ritual, raw material collection, etc.).

To use hunting and gathering as an example, our approach is to develop a theoretical framework which predicts the likely distribution of foraging activities throughout the prehistoric era. Such an approach will provide both the necessary understanding of why activities occurred where they did, as well as management information of sufficient specificity to allow the predictions that are needed.

Our initial task breakdown was to prepare separate sections on the activities listed in the preceding paragraph, as well as on relevant environmental variation. The results which emerged generally adhered to this intent, but with some overlap, expansion, and convergence. Both the hunter-gatherer and agriculturalist sections include discussions of settlement behavior, while the latter also deals with the hunting and gathering activities of agricultural peoples. The distributions of resources necessary for specialized activities are considered in most detail in the section on environmental variation.

3) Another question regarding level of specificity is the matter of archeological visibility. Should our efforts be on predicting the distributions of past activities, or should we also be concerned with the question of whether those activities are likely to have produced archeological remains?

Although the matter of archeological visibility is occasionally raised in the following pages, at the present time our knowledge is probably insufficient to tackle the matter in much detail. The task of merely predicting activity locations is formidable enough, and serves as our present goal. Yet the problem of whether or not specific activities leave behind archeological remains must someday be addressed, if the full economic benefits of predictive modeling are to be realized.

# ENVIRONMENTAL ASPECTS OF MODELING HUMAN LOCATING BEHAVIOR

Jeffrey S. Dean

## INTRODUCTION

As indicated by Cordell, DeBloois, Green, and Tainter, (1982), two approaches to predictive modeling are possible. One is based on an understanding of the processes that underlie the phenomena to be predicted, in this case the location and densities of archeological sites. The underlying processes here are those that determine the activity locating behavior of human societies in general and that of the residents of target localities in particular. An adequate theory of human settlement behavior is necessary for this type of predictive modeling. A second approach to predictive modeling is to use known site distributions and densities, as determined from extant samples of the archeological record, to predict the desired attributes of unsampled areas. The latter approach presupposes adequate samples on which to base the extrapolations, a condition that may be difficult both to achieve and to validate.

Different kinds of environmental information are pertinent to the two approaches to predictive modeling. The second approach involves variables of the modern environment that, on the basis of the samples underlying the model, have been empirically determined to covary with the archeological variables to be predicted, site location and density. Such environmental variables must have been adequately sampled along with archeological sites in the predictor samples that form the basis for the operation. This approach to predicting archeological site variables has been extensively employed by SARG (Dean 1978; Plog, Effland, Dean, and Gaines 1978) with mixed results (Judge 1978; Plog, Effland, and Green 1978).

Because habitats vary considerably from area to area, it is difficult to specify a universal set of environmental variables that would be satisfactory predictors of site parameters in all cases. Several kinds of variable, ranging from broad climatic patterns to locality specific distributions of plants and animals have been suggested as potentially useful in predicting site locations and densities. A problem in the use of such variables arises from the facts that the environment is not stable, and current environmental distributions may not accurately reflect those of the past. A second major problem in using specific variables of the modern environment as predictors of the distribution and density of human activity loci (past or present) arises from the high degree of intercorrelation among the predictor variables. Multicollinearity among predictor variables must be eliminated befor they can be used as independent predictors of aspects of the dependent variables, site locations and densities.

## PALEOENVIRONMENTAL VARIABILITY IN THE NORTHERN SOUTHWEST

Data on the modern environment are of limited relevance to predictive models based on a theory of human activity locating behavior. Subsistencesettlement systems are dynamic rather than static phenomena, of which only one aspect is environmental. Adaptive responses vary with a number of factors such as subsistence economy, sociocultural complexity, population, and environment. Hunter-

gatherer activity locating behavior is subject to quite different constraints from that of farmers. The sociocultural determinants of activity locating behavior are not stable, but change through time in response to changing social, economic, demographic, environmental, and other circumstances. Furthermore, the environment itself varies through time to create conditions not always comparable to those of the present.

A theory of human activity locating behavior, and any predictive model based on such a theory, must take into account the dynamic interrelationships among human adaptive behavior and changing environmental conditions. Knowledge of the modern environment in a target area is not sufficient to provide satisfactory predictions of these interrelationships. Accurate reconstructions of past environmental conditions and fluctuations are crucial to the development of a predictive model of site parameters based on a theory of human settlement behavior. Fortunately, recent research on the Colorado Plateaus (Euler et. al., 1979) provides high quality paleoenvironmental reconstructions that, with reservations, can be extrapolated into the areas of concern here. These reconstructions provide the environmental input for a dynamic model of past human settlement behavior that can be used to predict temporally and spatially specific aspects of activity locating behavior and, by extension, site locations and densities.

Environmental variability can be comprehended as resulting from low frequency processes (LFP) with periodicities longer than one human generation (c. 25 years) or high frequency processes (HFP) characterized by shorter periodicities. LFP are responsible for phenomena such as episodes of erosion and deposition along watercourses, while HFP are responsible for phenomena such as seasonal and annual climatic variability. Low frequency environmental processes usually are not apparent to humans, and environmental conditions created by LF processes probably are comprehended as stability. HFP variability, on the other hand, is apparent to human populations, and most behavioral buffering mechanisms are adaptations to expectable HFP environmental fluctuations.

Several measures of paleoenvironmental variability have been employed in the Southwest. LFP environmental variability is comprehended primarily through chronostratigraphic studies of alluvial sediments. Independent dates - archeological, radiocarbon, and tree ring - provide the means both for the temporal placement of units within individual stratigraphic sections and for correlating different stratigraphic sections. Chronostratigraphic studies with the necessary temporal control have been accomplished primarily on and around Black Mesa in northeastern Arizona (Euler et. al. 1979; Hevly and Karlstram 1974). These studies reveal episodes of deposition separated by periods of erosion or surficial stability (Figure 1). The alluviation curve, which is extrapolated from chronostratigraphic data and hydrologic reconstructions published by Euler et. al., (1979, Figures 4 and 5), represents the accumulation and erosion of alluvial sediments along drainages in the Black Mesa area. The same curve is a less accurate representation of relative hydrologic fluctuations, with rising water tables accompanying aggradation and falling groundwater accompanying erosion. The Black Mesa sequence is considered to generally represent LFP environmental variability in the northern Southwest, with the proviso that intraregional variations may be specified by future research. In gen-

eral, periods of aggradation or surficial stability without stream entrenchment would possess hydrologic conditions favorable for farming on floodplains; therefore, these intervals would be free of major LFP environmental stress on agriculturally based subsistence systems. Conversely, falling or depressed water tables and channel entrenchment would create LFP conditions inimical to floodplain farming, which would tend to stress agricultural subsistence systems.

Tree ring data are the most reliable indicators of HFP environmental variability because of their high temporal resolution and their strong positive correlation with climatic variability. The generalized Colorado Plateaus tree ring departure sequence (Figure 1), which is expressed in standard deviation units, is an accurate record of decadal variation in precipitation across the northern Southwest from A.D. 1 to the present. Two kinds of HFP paleoclimatic information are contained in this sequence. First, the amplitudes of the departures specify the relative amount of precipitation that characterized the individual decades. Second, the temporal patterning of dendroclimatic variability is revealed by the frequency structure of the departure sequence. The 310-380, 750-1000, 1350-1560, and 1730-1800 intervals are characterized by rapid oscillations from high to low values. The intervening periods exhibit greater persistence; that is, the change from high to low departures takes place over longer intervals of time.

Spatial patterning in HFP dendroclimatic variability is an important factor that heretofore has been overlooked in paleoenvironmental research. Recently, Plog (1983) measured the degree of spatial variability represented in contour maps of decadal dendroclimatic variability from 680 to 1970 by calculating the standard deviation of the station values for each decade (Figure 1). This measure varies through time to specify periods characterized by high spatial variability in dendroclimatic conditions interspersed among intervals when greater uniformity prevailed throughout the region. During periods of high spatial variability, interaction and exchange with other populations are viable means of offsetting local production shortfalls because different groups are likely to experience different degrees and kinds of subsistence stress. Conversely, when similar conditions prevail across the region, all areas are affected uniformly, and interaction becomes a far less useful way of alleviating local population resource imbalances.

An integrated picture of potential environmental stress on the inhabitants of the northern Southwest can be achieved by comparing the records of paleoenvironmental variability in Figure 1 with one another. The reconstructed environmental conditions and changes should provide a reliable basis for integrating paleoenvironmental variability with other aspects of human adaptive systems into a theory of human activity locating behavior that can be used to predict archeological site locations and densities.

## MODELING HUMAN ACTIVITY LOCATING BEHAVIOR

A theoretical approach to the prediction of archeological site locations and densities involves the modeling of human activity locating behavior. A large number of variables constrain the process of choosing a point in space at which to perform a particular activity or set of activities. Many of these constraints are environmental, and to the extent that we can model these

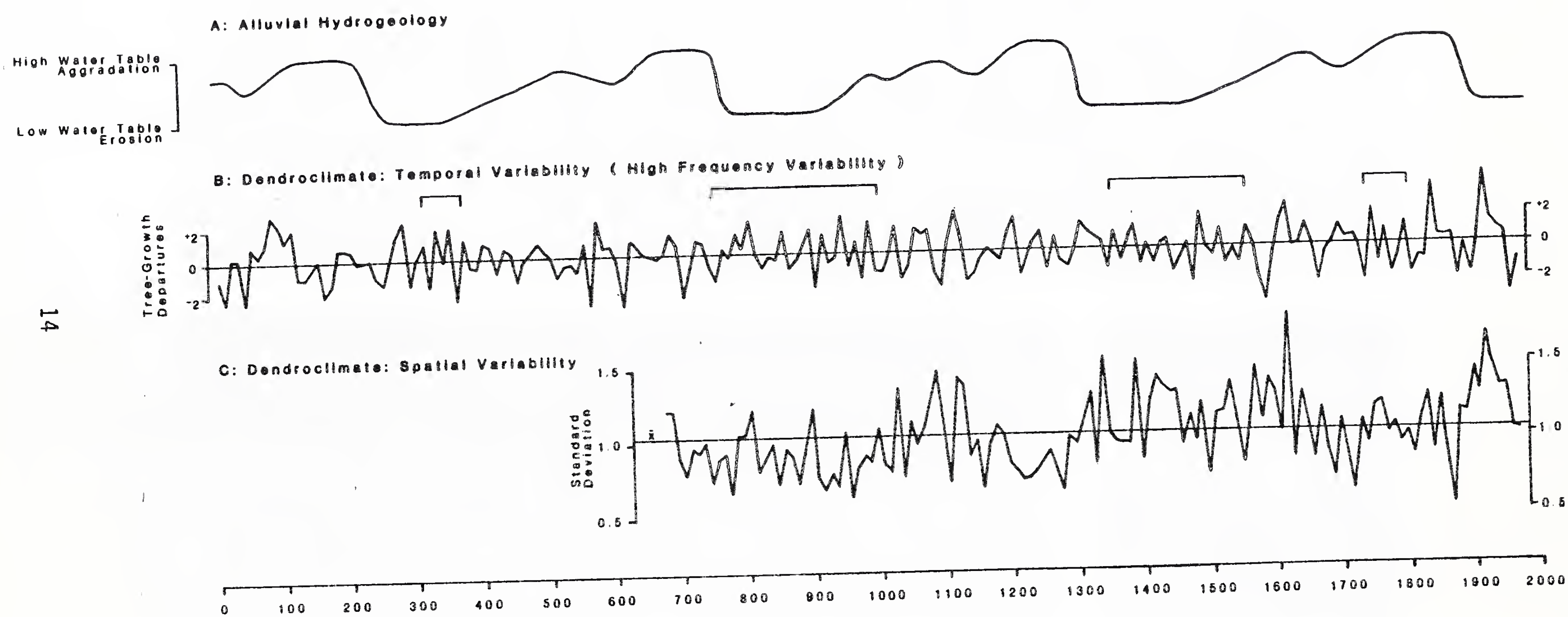



Figure 1. Paleoenvironmental Variability in the Northern Southwest A.D. 1-1970.

constraints, we should be able to identify potential loci of human use. Social or ideological constraints on activity locating behavior are difficult to measure and use as predictors of potential site locations in the absence of considerable data on sites in the area to be predicted. Since in most cases such data are not available (otherwise why predict site locations), behavorial variables generally cannot be used as predictors. Insofar as such behavioral factors have environmental correlates, environmental data should prove to be satisfactory predictors. A model of human activity locating behavior thus should attempt to specify not only direct environmental constraints on such behavior but also measurable environmental correlates of social and ideological constraints on such behavior.

## ENVIRONMENTAL FACTORS

Three conceptually separable but not wholly discrete kinds of environmental variable are likely to prove useful for this purpose. First is a class of "stable" variables that have not substantially changed in general character during the Holocene. This is not to say that there has not been considerable temporal variation in these factors; however, that variation has not been of sufficient magnitude to alter the general nature of the environment. These factors establish the overall limits of human adaptation in the study region during the Holocene. Thus, past inhabitants of the region faced general environmental conditions and relationships that are similar to those of the present. Because of this temporal stability, these variables can be used, with care, as times-table predictors of site locations and densities throughout the region.

Climate is one such stable variable. While it is true that there have been considerable fluctuations in various climatic variables, none of these have exceeded the bounds of the present climatic regime type (Schoenwetter 1962). The general climatic relationships that prevail today also characterized the past several thousand years. Thus, modern distributional and variational patterns in factors such as precipitation, temperature, length of growing season, and others should be satisfactory estimators of the past patterning of such variables. Gross topography is a stable factor that, except for extremely rare events such as the creation of a mountain by a volcanic eruption, has changed little throughout the span of human occupation of the region. Thus topographic variables - such as elevation, relative elevation, slope, exposure, view, land configuration, and others - are essentially identical to those experienced by past human populations. It is not surprising, therefore, that these variables appear to be good predictors of site locations.

Again excepting recent volcanic phenomena, the bedrock geology of the study region has changed little during the last five millennia. The resources controlled by regional geology - minerals, stone, water, and others have much the same distributions now as in the past and should be satisfactory predictors of site locations. The altitudinal vegetational zonation that characterizes the region has prevailed for millennia, although the boundaries of the zones may have varied in the past. Finally, the general composition of the plant communities within the vegetation zones has remained regionally fairly stable, although local variability has been high in some years.

A second class of environmental factor comprises variables that are subject to fluc-

tuations caused by low frequency LFP natural processes. Volcanic activity, as exemplified by Sunset Crater, falls into this category. During the last 2,000 years, the gradual rise and full of alluvial water tables on the Colorado Plateaus has been accompanied, respectively by aggradation and erosion of floodplains (Figure 1). Since farming would be heavily influenced by these variables, these LFP fluctuations should be good estimators of activity locating behavior.

Comparable fluctuations have not been demonstrated for the region of interest here; however, since the changes represent large scale processes, they probably are relevant to those forests in Arizona and New Mexico that flank the Colorado Plateaus. Slope processes seem to vary with the alluvial sequence, with slope erosion coinciding with alluvial aggradation and slope deposition with alluvial degradation. This relationship is far from clear cut, and slope processes probably are poor predictors of site locations. Elevational changes in vegetation zone boundaries are LFP events that might have predictive value if they could be accurately reconstructed. Pollen evidence for such fluctuations is somewhat equivocal, and until the polynological problems are resolved, this variable might best be avoided. The same conclusion applies to LFP changes in plant community compositions within vegetation zones. It seems probable for example, that the proportion of pinyon to juniper in pinyonjuniper forests varies systematically through time, but since these changes cannot be accurately retrodicted, this potentially useful variable is of little utility at present. Unlike the stable environmental variables, those subject to LFP fluctuations cannot be approximated by current measurements, but must be reconstructed by various techniques of paleoenvironmental analysis.

The third class of environmental factor, which also must be retrodicted, comprises variables that fluctuate in response to HFP natural processes. Most of these are retrodicted by dendroclimatic analyses, which have a temporal resolution of one year but which usually are collapsed into decadal measures (Figure 1). Amplitude (positive and negative departures from mean tree growth), high and low frequency temporal variability, and high and low spatial variability (Plog 1983b) are three different kinds of HFP dendroclimatic variability that have been reconstructed for the northern Southwest. Forest and range fires, natural or human caused, probably are HFP processes that affected human activity locating behavior. Dendrochronological analyses of fire frequency show considerable promise, but as yet no retrodictions of forest fire occurrence are available to be used in predicting past activity locating behavior.

With this background in mind it is possible to assess the potential effects of environmental conditions and changes on human activity locating behavior and on the potential of such activity loci being found by archeologists (site visibility). Following Tainter (this conference), it seems heuristically feasible to consider resources as aggregated or dispersed, to specify hunting-gathering and horticultural subsistence economies, and to look at several types of natural resources that might constrain activity locating behavior. These resources include wild plant and animal foods, raw materials for manufacturing artifacts and facilities, water, arable land, and ceremonial resources. A few non-environmental phenomena - social organization, exchange, and communication - are

considered within the aggregated dispersed dichotomy.

## RESOURCE ATTRIBUTES

Resource aggregation can be either spatial or temporal depending on whether they are clustered in different localities or at different times. Knowledge of environmental processes that determine resource distributions is crucial to the prediction of spatial and temporal variability in resource dispersal and aggregation and of the human behavior associated with the utilization of these resources. Specification of the ways in which the three classes of environmental factor - stable, LFP, and HFP - affect these resource characteristics is an important component of a model of human activity locating behavior that is useful for predicting archeological site occurrences.

Aggregated resources are likely to be exploited in ways quite different from those used to extract dispersed resources, since resource aggregation fosters concentration of exploiting activity. These differences are likely to produce substantial differences in the archeological visibility of the sites at which these activities took place. Such visibility is a function of the localization, intensity, duration, and repetition of activities at the activity locus. Thus, the exploitation of aggregated resources is far more likely to produce recognizable archeological sites than is the utilization of dispersed resources unless the latter is particularly intense, localized, or both. Site visibility also is a function of postoccupational transformations of the site and its environs. Environmental data that characterize the spatial and temporal structure of resource distributions and that specify the transformations undergone by particular habitats are crucial elements in the modeling of human activity locating behavior and the prediction of site occurrences.

## HUMAN RESOURCE EXPLOITATION

Hunter-gatherers are likely to exploit resources differently from horticulturalists. Hunter-gatherer subsistence often involves the successive utilization of various resources, a practice that produces a series of temporarily occupied camps. One of these may be a central residential camp that is used more intensively than the others. This pattern is most likely to develop through the exploitation of aggregated resources where concentration of resources rewards prolonged occupation and systematic reuse of the area. Concentration of resources, distance from the central camp, and resource processing time determine the intensity, duration, and repetition of site use. High values for these variables should produce visible sites. Even higher values for central loci, whether they are associated with specific resources or situated to maximize access to a number of resources, will make these sites more visible.

Hunter-gatherer exploitation of dispersed or highly mobile resources probably takes a more logistic form. Many dispersed plant and animal resources are collected on an ad hoc basis in connection with other activities. The hunting of dispersed game such as deer and mountain sheep can be accomplished without benefit of special facilities by small, mobile parties. Such gathering and hunting activities, like the resources, are dispersed and of low intensity, duration, and recurrence. Because of this, these activities produce sites of low to no visibility. Exploitative activities that artifically concentrate otherwise dispersed resources are likely to be fairly

intense, persistent, and recurrent. These attributes combined with the common utilization of special facilities for resource concentration enhance the visiblity of sites produced by these activities. Similarly, dispersed resources that are virtually ubiquitous and regenerative may be repeatedly exploited at specific loci whose intense and repeated use produces visible sites. Thus, the nature of the resources and the methods used to exploit them are prime determinants of site distribution and visibility, and knowledge of these variables should enhance the predicability of site occurrence.

Resource utilization by horticulturalists differs in a number of ways from that of hunter-gatherers. The primary resources used by such groups, arable land and water, are highly aggregated and tend to produce aggregated activity patterns. This factor coupled with the high intensity, duration, and recurrence of resource use result in a pattern of more or less permanently occupied habitation loci situated near arable land. Exploitation of aggregated nonagricultural resources tends to involve the use of base camps near the resource. This pattern is somewhat similar to that of hunter-gatherers, but differs from it in that much of the processing, storage, and consumption of the resource occurs in the habitation sites. Thus, horticulturalist utilization of such resources tends to be less intense and of shorter duration than hunter-gatherer use, although the repetition rate may be quite similar. These factors tend to produce sites of fairly high visibility.

Horticulturist utilization of dispersed agricultural resources may involve a pattern of shifting agriculture in which use of suitable loci is intense, but of fairly short duration, and low recurrence. Sites produced by these activities should be fairly visible and occur in a highly dispersed pattern. Alternatively, such resources could be extracted by people seasonally resident at the field loci who then bring the crops into "permanent" habitation loci for processing, storing, and consumption. In this case, a pattern of highly visible central habitation loci surrounded by less visible field residential sites develops. Horticulturalist exploitation of dispersed or mobile nonagricultural resources should resemble that of hunter-gatherers and should produce similar sites of comparable visibility.

## RESOURCE UTILIZATION

Given the above considerations, it is now possible to consider the effects of components of the three environmental classes-stable factors - LFP fluctuations, and HFP variability - on the character and distribution of various resources and on changes in these attributes. Control of these factors provides a foundation for a processual understanding of resource availability and of the human utilization of these resources. Undoubtedly, such a model will enhance our ability to predict those aspects of site distribution that are caused by or related to environmental factors. More importantly, such a model will help explain observed relationships among site distributions and various environmental variables.

### Wild Plant Food Resources

#### Dispersed

General climatic, topographic, geological, and vegetation zonation factors tend to disperse plant resources across broad areas. LFP factors fostering dispersal of resources include high alluvial water

tables-aggradation (which creates extensive, uniformly favorable floodplain habitats), stable or depositional slope processes, and retreat of a vegetation zone boundary. HFP fluctuations that favor dispersal include high frequency temporal variability and low spatial variability in climate. Dispersal of wild plant foods, therefore should be high on floodplains during intervals characterized by alluviation and uneroded surfaces (Figure 1). Resource dispersal in non-floodplain areas probably occured during the 750-1000 period of low spatial and high temporal dendroclimatic variability.

### Aggregated

Topography, geology (substrate and soils), and plant community composition tend to aggregate resources within the general limits of plant distribution established by stable environmental factors. Several LFP variables have aggregative effects. Volcanic eruptions abruptly create new conditions that may aggregate plant resources until succession restores dispersal. Low alluvial water tables-degradation creates patchy habitats that aggregate floodplain resources. Therefore, floodplain aggregation should have occured during intervals of erosion and low water tables (Figure 1). Slope erosion aggregates resources on stable patches amid disturbed areas. Advancement of vegetation zone boundaries can temporarily aggregate the advancing species. Changes in plant community composition, as an increase in the ratio of pinyon to juniper, can also temporarily aggregate a resource. HFP changes probably are too rapid to effect the distribution of food plants other than annuals; however, these changes can effect the productivity of resources in ways that approximate aggregation.

Low frequency climatic variability (Figure 1) may aggregate the productivity of plants that are adapted to the trend (positive or negative). High spatial variability in climate, if it persists long enough, could aggregate resources into discontinuous pockets. Fires rapidly create fairly short-lived aggregations as plants successively colonize the burned area. Finally, human activity, such as the establishment of fields, aggregates wild plant resources.

## Predictive Implications

Both hunter-gatherer and horticulturalist exploitation of wild plant foods should be more visible in areas and time periods characterized by resource aggregation. Stable environmental factors that aggregate plant resources can be used as predictors of potential loci of high visibility extractive sites. Furthermore, we might expect wild plant food extraction to have clustered in the vicinity of Sunset Crater in the late 11th century and on floodplains during the 225-350, 750-900, 1275-1500, and 1875-present intervals. Conversely, high visibility exploitation of aggregated resources on the slopes probably intensified in the intervening periods.

Proximity of habitation sites to floodplains probably would eliminate the need for horticulturalists to inhabit other loci during the collection of floodplain plants, if indeed any except those associated with fields were available. During periods of decreased crop and wild plant productivity- such as intervals of flood plain erosion, low precipitation, or both (Figure 1) - exploitation of dispersed plant resources might have intensified enough to produce visible remains.

### Wild Animal Food Resources

#### Dispersed

Generally, wild animal resources can be considered to be dispersed, either because their small size or mobility evens out their distributional densities. The hunting of individual dispersed large animals (deer and mountain sheep) is an activity that, because of its low localization, intensity, duration, and repetition, produces sites of low visibility and wide spacing. Small, dispersed animals are taken on an ad hoc basis that rarely produces sites. Much hunting of dispersed prey involves the artificial aggregation of the resource.

#### Aggregated

Large and small game are aggregated naturally by the stable elements of the environment, particularly vegetational distributions. Small animals are more susceptible to aggregative factors than are large, mobile animals. Small animal aggregation accompanies the aggregation of the plant resources on which they live. In addition, small animals are aggregated by human activities, such as farming, that aggregate plants. Natural aggregation among large animals is more a function of behavior; some animals, such as elk and bison, congregate in large, but mobile, herds. Large animals such as bison and pronghorns, commonly are artifically aggregated through the use of facilities such as pens, traps, and jumps. Small animals are artificially aggregated by drives into ambushes or nets.

#### Predictive Implications

Collection of individual dispersed large or small game is a low visibility activity whose loci can be only generally predicted on the basis of the current distributions of these animals or of plants favored by them for food and cover. Temporal variability in plant and animal distributions reduces the efficacy of their modern expressions as predictors of individual hunting loci. The exploitation of artificially aggregated game leaves traces whose visibility is proportional to the degree of localization, intensity, duration, and recurrence of the activity. Permanent facilities for aggregating big game-such as traps, pens, and jumps-are especially visible, while portable facilities for aggregating small game, such as nets, leave no traces of the loci of their use. Precise locations of permanent facilities cannot be accurately predicted, since they can occur in a wide variety of suitable places. General expectations of areas in which such facilities are likely to occur, however, can be developed on the basis of known animal distributions, food and water supplies, and topographic features that lend themselves to the aggregative function. The likelihood that small animals will be aggregated on floodplains during low water table-degradation intervals confers little predictive value because of the virtual invisibility of sites produced by the collection of such resources. The same limitation applies to the collection of small animals artificially aggregated around fields.

### Raw Materials

#### Dispersed

Stable environmental factors tend to disperse raw material resources. Even prescribed geological resources, such as building stone, are so widely distributed that they can be treated as dispersed. Some LFP factors, such as floodplain

aggradation-high water tables or vegetation zone changes, disperse raw materials such as clay and shrubs. HFP variables have little effect on raw material dispersal because the processes that create these materials-rock formations, surficial deposits, forests-have response time too slow to be affected by HFP variability.

### Aggregated

Of the stable environmental factors, geology is the main raw material aggregating process through its control of the distribution of minerals and stone used for implements, ornaments, trade items, pigments, building stone, pottery clay, and the like. The effects of topography, substrate, and soils on vegetation aggregates biotic raw materials as well. Vegetational zonation (especially in edge areas) and the composition of plant communities aggregate biotic resources (such as the isolated stands of Douglas firs in the canyons of the Colorado Plateaus). LFP variables have important aggregatory effects as well. Volcanic eruptions concentrate mineral and stone resources. Alluvial processes aggregate clay sources both through deposition of clay and through the localized exposure of such deposits by erosion. HFP variability has little effect on the aggregation of raw materials except perhaps for plants such as yuccas and shrubs.

### Predictive Implications

Exploitation of dispersed raw materials is likely to lack the localization, intensity, duration, and repetition necessary to produce highly visible sites. Even heavy exploitation of a dispersed raw material can leave few traces. Chacoan builders extracted at least 250,000 trees from the forests around the canyon, yet no evidence of this activity has come to light. Exceptions to the low visibility of this type of activity involve artificial aggregation of dispersed resources that either requires visible facilities, or that leaves recognizable traces on the resource itself; for example, quarries. Such locations are difficult to predict from environmental data because of the dispersal of the resource; some information on the distribution of human activities (sites) probably is necessary for this purpose.

Exploitation of naturally aggregated raw materials is likely to assume a logistic pattern with people coming to the resource from residential loci. Extractive sites at these loci should be fairly visible, although those that require little in the way of on-site processing will be less so. Quarry sites for flaking stone or building stone are much more visible than are quarries for pottery clay or mineral pigments because little or no processing occurs at the latter. Because LFP and HFP variability has little effect of raw material occurrence, stable environmental factors are the best predictors of localities in which raw material extraction and processing sites are likely to occur.

## Water

### Dispersed

Except for air, precipitation is the most widely dispersed natural resource. Even so, spatial and temporal variability is high, the former controlled by stable climatic and topographic factors and the latter by low and high frequency climatic processes. Alluvial water supplies are dispersed during intervals of high water tables and aggradation when ground water is distributed fairly uniformly throughout the sediments.

## Aggregated

Topography aggregates surface water into drainage channels and catchments such as ponds and lakes. Geological factors aggregate the surface release of ground water at springs and seeps. Low alluvial water tables and stream entrenchment aggregate water in deep channels and localized seeps. Some HFP variables aggregate water either spatially or temporally. Annual fluctuations in the amount of precipitation and trends in precipitation create temporal aggregates of relative moisture. High spatial variability in climate produces areal patchiness that involves the relative aggregation of precipitation in some areas as compared to others.

## Predictive Implications

Because of the ubiquity of the resource, the direct collection of precipitation, even if it involved special facilities, is too diffuse an activity to have any predictive value. High, dispersed alluvial water tables can be tapped in many places by techniques that leave few traces. Only when ground water is tapped by large, communal wells that are used repeatedly over a long period of time are visible features produced. Because dispersed ground water is more or less equally available throughout a floodplain, hunter-gatherer camps and horticulturalists habitations probably are evenly distributed or are clustered with respect to some other resource(s) during high water table-aggradation intervals (Figure 1).

Exploitation of aggregated water supplies can leave few traces, although hunter-gatherer and horticulturalist sites commonly are situated near aggregated water sources such as drainage channels and springs. The ubiquity of drainage channels reduces their value as predictors of site occurrence. Usually a large number of suitable use loci are situated near one or more stream channels. Techniques for acquiring water are simple and leave few traces unless water transportation or storage facilities-such as canals, sumps, or reservoirs-were involved. In such cases visibility and predictability are likely to be high. Temporal changes in the availability of aggregated water sources are predictable; the locations of such sources are less so. Aggregation of alluvial water supplies occurs during intervals of low water tabledegradation. At such times (Figure 1) sites might cluster around aggregated water resources, and water transportation and storage facilities might occur.

## Arable Land

## Dispersed

Arable land (land that under the proper conditions can be expected to produce a crop) is widely dispersed in some areas in response to the effects of stable environmental factors. Vast areas in the forests north of the Mogollon Rim could have been farmed aboriginally as a result of a salubrious combination of climatic, topographic, gelogical, and edaphic conditions. Similarly, the extensive floodplains of the large rivers of southern Arizona provide huge tracts of dispersed arable land. Spatial variability in the potential productivity of these areas is controlled in large measure by the stable factors: climate, elevation, substrate, soils, and others. Temporal variability in productivity is controlled by LFP and HFP environmental flucturations. Productivity in most areas varies with precipitation and temperature. That of the southern Arizona floodplains may have fluctuated with hydro-

logical transformations similar to those of the Plateaus (Figure 1), although there is little evidence for the occurrence of such fluctuations in the Desert.

### Aggregated

Despite the existence of large areas of arable land, at a regional scale of analysis this resource is highly aggregated. Most stable environmental factors operate to aggregate arable land. Climate, topography, bedrock and surficial geology, and soils interact to create discontinuous aggregates of arable land that vary widely in character. As a result, aspects of the two remaining stable factors, vegetational zonation and composition, commonly are good indicators of arable land.

Some LFP fluctuations aggregate arable land. Ash deposits from volcanoes may create pockets of arable land where none existed before or increase the productivity of affected areas. The erosion of floodplains reduces arable land to localities where favorable conditions create land-water congruencies that allow farming. Slope erosion can create pockets of arable land among denuded areas. Low frequency climatic oscillations tend to aggregate productivity in time and to reinforce contemporary factors that promote spatial aggregation of resources. High spatial variability in climatic aggregates productivity across space and reinforces the aggregative effects of alluvial hydro logical transformations. Natural or man-caused fires may have temporarily enhanced agricultural productivity.

### Predictive Implications

Arable land should be most relevant to the understanding of horticulturalist activity locating behavior, particularly that connected with farming. Since farming is a time consuming, long duration task that provided much of the subsistence base of Southwestern horticultural groups, habitation loci tend to be located near the fields. Other resources tend to be exploited logistically from the residential loci.

The localization, intensity, and duration of locus use produce highly visible sites, the habitation sites of most archaeological surveys. Dispersed arable land should produce a settlement pattern in whch sites are similarly dispersed or are clustered around other features of the natural or social environments. In such cases, the predictive potential of arable land alone is low, and other environmental or archeological data must be used for this task. If the human population of a dispersed farming area becomes dense enough, congregation around central sites may occur, but arable land would not be a good predictor of this phenomenon.

In areas of aggregated arable land, horticulturalist occupation is likely to be clustered in ways that are predictable on the basis of the distribution of arable land. Increasing population may eventually lead to the development of central sites concerned with control of farmland and perhaps exchange, whose locations should be fairly predictable with arable land or soils data. LFP environmental fluctuations that transform a dispersed arable land distribution into an aggregated one should result in the concentration of previously dispersed communities around the newly aggregated resource. Such aggregative trends might be expected during low water table-degradation intervals (Figure 1) when high populations precluded mobility as a response to changed circumstances. Aggre-

gation might also be expected as a reflection of heightened exchange activity employed during periods of high spatial variability (Figure 1) to offset localized population-resource imbalances.

## SITE LOCI

An important determinant of site occurrence is the distribution of suitable loci for activity performance. Habitation probably has the most stringent requirements in this regard, while specialized activities can occupy a wide variety of loci near the resources being exploited. Thus, habitation site occurrences ought to be easier to predict than those of limited activity sites. Certain locations can be eliminated on the basis of physical attributes such as steep to vertical slopes, extreme elevation, substrate (few activities ever were performed on Chinle formation exposures), unusable soils and so on. Once such areas are omitted suitable loci can be either dispersed or aggregated. When dispersed, prediction may be trivialized by the ubiquity of the resource. On the other hand, when suitable locations are aggregated, prediction of potential site occurrences becomes much more meaningful.

People tend to build on stable, dry locations where neither rainfall nor ground water can get into the structures. This trends to produce a pattern in which habitation sites are located on eminences or slight rises on the margins of floodplains or other farmed areas. Habitation on floodplains usually occurs only when the alluvial surface is fairly stable (neither aggrading nor eroding) and when water tables are low. Surface stability prevails under conditions of low water tables-degradation similar to those of the present. Thus, floodplain surfaces may have been loci of human activities during the 225-350, 750-900, 1275-1400, and 1875 to present intervals. In contrast, the intervening periods probably were characterized by habitation on the margins of floodplains and perhaps on the slopes above. Thus, some knowledge of the temporal structure of the human occupation of an area will permit accurate predictions of whether sites are likely to occur on the slopes, on the floodplains, or in both areas.

## SITE VISIBILITY

As mentioned previously site visibility is first a function of the localization, intensity, duration, and repetition of utilization of the locus. Natural and behavioral transformation processes are continually at work on the site, especially after it is abandoned and maintenance no longer retards disintegration. Concern here is with natural processes that destroy or obscure archaeological sites and with ways in which knowledge of such processes can be used to estimate the likelihood that undetected sites exist in an area, to predict where they are likely to occur, to devise tests to discover if such sites do in fact exist, and to specify the potential impact of various activities on such sites.

Any catastrophic natural event - a volcanic eruption, a landslide, a forest fire - can destroy or obscure archaeological sites. If such events can be dated, a basis exists for estimating their potential impact on human activity loci that predate the event. It is fairly certain, for example, that sites lie buried under lava flows emitted by Sunset Crater. It also is virtually certain that such sites have been extensively damaged and that few expectable modern activities in the area could have much impact on them. Similarly, landslides of known date can be expected to have obscured sites, sites that are unlikely to

suffer damage from all but the most land altering activities in the area.

Less spectacular, but more important, than catastropic events are the effects of ongoing low and high frequency natural processes in obscuring and destroying sites. The chronology of alluvial and hydrological events (Figure 1) can be used to predict the probable occurrence of sites buried by alluviation and slope processes on and adjacent to the Colorado Plateaus.

Since people tend to build on stable surfaces, most construction on floodplains occurred during intervals of low water tables and degradation. In many cases such sites were totally buried to considerable depths by the subsequent accumulation of sediments. Such sites are now completely invisible unless they have been exposed by more recent erosion or by subsequent human activities. Chronostratigraphic or even terrace morphology studies usually can establish whether or not a particular drainage has deposits of the proper age to contain buried sites. If such deposits are present, a careful search of eroded areas, arroyo walls, and and of areas disturbed by human activity such as quarrying or road building, is quite likely to disclose evidence, in the form of material items or structures, of buried sites and of the depths of these features. Given these facts estimates of the potential impact of a planned activity-logging, road building, miningon buried features is easily made. In the absence of natural or man made exposures, cores can establish the presence and depths of subterranean surfaces that might support archaeological sites. Knowledge of the vertical distribution of such unconformities allows a realistic assessment of impact on buried archeological sites.

Geomorphic studies also can disclose the occurrence at the present ground surface of older depositional units that might contain sites. Mapping of these areas provides an ideal strategy for predicting site occurrence. Obviously, any surface that postdates the human occupation of a locality need not be investigated. Rather, attention can be focused on surficial remnants that date to the time of human occupancy. Geomorphic studies also can specify slope areas that have been disturbed by erosion or buried in slope wash and can indicate surfaces of the proper age to contain sites or of an age too recent for site occurrence. A fairly modest reconnaissance of Holocene surficial deposits in a particular area can pay disproportionate dividends in markedly enhancing our ability to identify areas where visible and buried sites are likely to occur and to estimate the potential impact of the planned activity on surface and buried sites.

## CONCLUSIONS

The purpose of this long review of environmental impact on human activity locating behavior is fourfold. First, a preliminary attempt is made to develop an environmental component of a model of human activity locating behavior that can be used as a basis for predicting and explaining archeological site occurrences. This was done by assessing the impact of three classes of environmental factors - stable, low frequency, and high frequency - on the aggregated or dispersed distributions of several kinds of resources - wild plant and animal, raw materials, water, and arable land. Human behavior was incorporated by assessing the activity locating implications of each of the resource types for hunter-gatherer and horticultural subsistence systems. Second, an attempt is made to use the provisional model as a basis for

specifying variables of the present environment that can be used as predictors of site occurrences and for explaining why such variables are or are not satisfactory predictors. Using this theoretical approach, without benefit or hinderance of actual data, it proved possible to identify variables that should be satisfactory predictors of site occurrences and to specify the conditions under which such predictions should be most applicable. The stable environmental factors are good estimators in many circumstances because they have not changed appreciably since the site were produced. LFP and HFP variability appear valuable for situations in which activity locating dynamics can be modeled and in which relevant environmental transformations can reasonably be inferred. The contributions of LFP and HFP variability to site occurrence prediction vary with the behavioral and environmental interrelationships involved in particular cases.

Third, the model is used to investigate potential distributions of suitable loci for various activities that produce archeological sites and to assess the utility of such distributions for predicting site occurrences. Stable factors, particularly topography, and the distribution of arable land appear to be important potential determinants of the locating of habitations by horticulturalists. Finally, brief consideration is given to the effects of low and high frequency natural processes on site visibility and on the potential impact of modern activities on sites. It is possible using minimal alluvial stratigraphic information to determine the likelihood of sites being buried in floodplain sediments, to estimate the stratigraphic positions even of totally unobservable sites, and to accurately assess the potential impact on such sites of various kinds of work in an area.

Perhaps the major implication of this exercise for the accurate prediction from environmental data alone of localities in which sites should or should not occur concerns the nature of the resources that could have been exploited by the prehistoric inhabitants of a target area. If resources are evenly dispersed throughout the area, human exploitation of such resources is likely to be dispersed as well. As a result, both site visibility and predictiability will be low. If, on the other hand, resources are aggregated, human utilization is likely to have been clustered also. In such cases site visibility and locational predictability should be fairly high.

The predictive consequences of the above considerations are clear. If predictability is enhanced by aggregation of resources, then those resources that are aggregated, or environmental variables that are used as modern surrogate measures of such resources, should be the best estimators of site occurrences. For example, in an area in which arable land is evenly dispersed across the landscape, arable land is likely to be a poor predictor of site distribution. Aggregated resources, however, such as water sources or suitable locations for habitation structures, are likely to be good estimators of site occurrence. In such a situation, even if habitations were located to maximize access to arable land, the ubiquity of that resource reduces its role as a determinant of site location and enhances the role of secondary resources that are more discontinously distributed. In order to maximize the efficiency of a predictive model based on environmental criteria, aggregated environmental variables should be emphasized, perhaps within areas defined by dispersed variables. This would result in a nested model in which broad areas defined on the

basis of dispersed variables are divided into smaller zones specified by the discontinuous distributions of aggregated resources. These considerations have survey implications as well. Areas in which resources are dispersed require more intense sampling than do areas in which aggregation of resources permits better stratification of the sample.

It should be stressed that the model developed herein is a provisional construct that will need much testing and reformulation before it can provide wholly satisfactory predictions of site occurrences and explanations of why sites occur where they do and do not occur where they do not. The modeling studies based on actual archeological data that appear in this volume disclose relationships among the environment and human behavior that will begin the long process of testing and reformulation that eventually should result in a theory of human activity locating behavior that can refine predictions of site occurrences and explain why the predictions do or do not work. In the meantime, I will be satisfied if I have conveyed even an impression of complexity of activity locating behavior and the concomitant necessity to implement immediately the theoretical and empirical work necessary for an adequte understanding of this important aspect of patterned human behavior.

# FORAGERS IN THE SOUTHWESTERN FORESTS

Joseph A. Tainter

## INTRODUCTION

Before proceeding to our main discussion it will be useful to briefly outline the orientation, terminology, and limitations of the approach that will be developed.

The geographical orientation of the study is the Southwest uplands, particularly as represented in the National Forests. The environmental zones of major interest are traditionally labeled as follows:

Lower Sonoran: below 500 feet elevation, a desert zone dominated by creosote, yucca, broom snakeweed, and various grasses.

Upper Sonoran: 5000-7000 feet elevation, dominant grassland character, juniper and pinyonjuniper in the upper portion.

Transition: 8500-9500 feet elevation, Ponderosa pine and Gambel's oak dominate, grading into pinyon pine at lower elevations and Douglas fir with aspen at higher elevations.

Canadian: 9500-12000 feet elevation, densely forested with spruce, fir, and aspen (Bailey 1913: 16; Elmore 1976: 157, 173).

Two other terms are occasionally used: the pinyon-juniper zone occurs in the upper portion of the Upper Sonoran zone, while the mixed conifer zone characterizes the lower end of the Transition zone and the Upper Sonoran/Transition ecotone. The emphasis in this chapter is on higher elevation, forested areas.

Throughout this chapter reference will be made to the term "high elevation," usually without specifying what elevation this means. This is done deliberately, for two reasons. In some places the meaning is left vague because the term is intended to merely signify any location higher than where the majority of prehistoric Southwestern settlements were situated: the Lower Sonoran and lower to middle portions of the Upper Sonoran zones. In other places the meaning is left vague to accommodate the varying geography of the Southwestern National Forests. In the drier areas of southern Arizona and New Mexico, life zones extend into higher elevations than in the wetter northern parts. The limiting characteristics of high elevation biotic zones accordingly take effect at differing altitudes. For this reason, no absolute definition of what is meant by "high elevation" can be given. The meaning is hopefully clear in context.

This study is a limited undertaking. If focuses on the major, optimal resources likely to have been exploited at higher elevations. It does not devote major attention to floral and faunal resources of secondary importance, nor to such things as symbolic or ritual use of high elevations and the resources found there. The present chapter is not intended to be a comprehensive theory of the totality of hunter-gatherer uses of forests. It is instead an exercise in theory building. Its objectives are both to provide some theoretical underpinning for predictive models relating to high altitude use, and to initiate what must become a detailed exercise in explanation and theory construction.

## LOCATIONAL DETERMINANTS OF HUNTING AND GATHERING ACTIVITIES

The present attempt to understand the distribution of hunting and gathering activities on the Southwestern Forests is based on assessment of three factors; zonal productivity, predator behavior, and prey characteristics and behavior.

### Zonal Characteristics

There are two measures that are of importance for understanding the usefulness of environmental zones for human exploitation. The first is: Net Above-Ground Primary Production/Primary Biomass

This ratio measures the relative amounts of primary production that are available to support higher trophic levels in an energy pyramid. All consumer life depends on this ratio. Where biomass and respiration rates are high relative to primary production, the amount of production available for consumers is low, so that little animal life (including human) can be supported.

The second measure is: Secondary Biomass/ Primary Biomass

Secondary biomass consists of all consumers in an ecosystem. This ratio measures the relative availability of faunal resources in a zone. Some values for these characteristics are given in Table 1, for selected kinds of ecosystems. This table also shows the concordance between these abstract ecosystem types and Southwestern life zones.

Table 1. Zonal Productivity Characteristics[1]

| Zone | Southwestern Equivalent | Net Above-Ground Primary Production (g/sq. m/yr) | Primary Biomass (g/sq. m) | Secondary Biomass (g/sq. m) | NAGP / Primary Biomass | Secondary Biomass / Primary Biomass |
|---|---|---|---|---|---|---|
| Desert & Semi-Desert | Lower Sonoran & lower portion of Upper Sonoran | 40.0 | 700 | 44.0 | .06 | .06 |
| Woodland & Shrubland | Upper Portion of Upper Sonoran | 700.0 | 6000 | 4.7 | .12 | .0008 |
| Temperate Evergreen Forest | Transition & Canadian | 1300.0 | 35000 | 10.0 | .04 | .0003 |

[1]After Whittaker (1975: 224, 226) and Kelly (1980: 13, 20).

Ranked in terms of Net Primary Production/ Primary Biomass, these zones would be of decreasing use to herbivores as follows: Upper Portion of Upper Sonoran (Woodland and Shrubland) Lower Sonoran and Lower Portion of Upper Sonoran (Desert & Semi-Desert) Transition and Canadian Zones (Temperate Evergreen Forest).

Ranked in terms of faunal production, these zones would be ordered as follows: Lower Sonoran and Lower Portion of Upper Sonoran (Desert & Semi-Desert) Upper Portion of Upper Sonoran (Woodland and Shrubland) Transition and Canadian Zones (Temperate Evergreen Forest).

It is clear from Table 1 that the juniper and pinyon-juniper belt yields the most favorable overall productivity of herbivorous resources, followed by the deserts and semi-deserts of lower elevations. However, more of the primary biomass of lower elevations can be converted into secondary biomass, with the result that when faunal productivity is considered, the relationship between the two zones is reversed. Whether in terms of floral or faunal productivity, both the Lower and Upper Sonoran zones are preferable to the Transition and Canadian Zones (Hevly 1983).

These statistics suggest that high elevation, forested areas are of secondary desireability for human foraging. In the Southwest, areas of higher elevation are characterized by higher primary biomass, higher precipitation and runoff, shorter growing seasons, and lower Effective Temperatures (ET) (Cordell 1979: Maps 2, 3, 4). Net primary production declines in higher elevations (Whittaker 1975: 205). In the vegetation of such zones, primary production is disproportionately invested in such things as woody tissue, leaves, evergreen needles, moss, and lichens (which are partially or totally enedible by humans), or in poor sources of nutrition, such as greens or berries.

A major limiting factor in such settings is sunlight, so that disproportionately more primary production is invested in leaves and needles, while cooperation for sunlight selects for height and for placing branches selects for height and for placing branches as high as possible. There is relatively little understory production in the most densely forested areas. The seeds of such trees tend to be inaccessible, placed at the ends of branches, and of a form which makes their use difficult (e.g., pine nuts). Conversely, at lower elevations (areas of lower runoff), primary production becomes increasingly accessible (that is, in greater abundance, and in a form more useable by human populations) (Kelly 1980: 16, 19, 22).

In such areas of high primary biomass there tends to be decreased productivity and accessibility of secondary biomass. Animals are often comparatively dispersed in such zones. Coupled with the visibility reduction caused by the dense vegetation, this suggests that it is often less advantageous to monitor for faunal resources (Kelly 1980: 24). Very often, in high primary biomass settings, food items tend to be dispersed, and the location of one does not predict the location of another. Except for monitoring such locations as game trails and water courses, this condition selects for a strategy of essentially random foraging (Kelly 1980:51). It is important, however, to note that this tendency may be somewhat modified where high primary biomass occurs in a setting of high topographic diversity, as in the Southwest, for increased environmental patchiness will increase prey aggregation, and make prey locations more predictable.

Given the low capacity of high primary biomass/high runoff settings to support herbivores and carnivores, it is to be expected that hunting and gathering populations using such zones on either a logistical (resource extraction) or residential basis would be faced with the necessity of frequent movement (Kelly 1980:40, 49).

## Predator Behavior

A major framework for understanding predator behavior, developed in the field of ecology over the past several years, is Optimal Foraging Theory. Also termed the diet breadth model, it suggests (among other things) that foragers optimize the number of resource types in the diet relative to search and pursuit times (MacArthur and Pianka 1966). A volume edited by Bruce Winterhalder and Eric Alden Smith (1981) has recently explored its application to human foragers.

Optimal Foraging Theory, like the Principle of Least Effort (on which it is based), is a highly simplified approach to a complex, multivariate reality. The application to human populations of foraging models developed for other species adds further reason for caution. Ultimately, Optimal Foraging Theory (again, like the Principle of Least Effort) may prove most valuable in focusing our attention on the various factors that condition behavior to adhere to or depart from its predictions.

Applied to human populations, Optimal Foraging Theory presents several points at which anthropologists (or even biologists) might hesitate. It is based, for example, exclusively on predator-prey interaction, complete ignoring competitive relations among predators. It does not presently take into consideration the human ability to plan, to store, or to share information, nor the fact that, while foraging, human populations also do other things, such as monitor future resources, acquire lithic materials, and the like (but cf. Moore 1981).

Despite these caveats, there are still elements of Optimal Foraging Theory that are of value in understanding the distribution of human foraging activities. These elements should not be applied too literally to our present needs, but they may be useful for general assessments of such things as concentration vs. dispersion of activities, use of different types of patches, length of foraging expeditons, and selection of prey.

An optimal forager is selective in a rich environment, and less discriminating in a poor one (Winterhalder 1981:25). Optimal predators 1) prefer more profitable prey, 2) are more selective when profitable prey are common, and 3) ignore unprofitable prey which are outside the optimal set regardless of how common they are (although among several species, a condition of low prey density results in the predator eating all prey as encountered). When prey density is low, a predator should use a cheap, low return method of foraging. When prey are abundant, the predator should switch to a high cost, high yield, selective method (Krebs 1978:29-35, 59). Among those species that constitute the optimum diet breadth of the forager, prey will be taken in proportion to their abundance in the environment (Yesner 1981:150).

In heterogenerous environments, foragers will feed preferentially in rich resource patches (Moore 1981:200). Under what is termed the Marginal Value Theorem, predators are expected to search in a rich patch until the marginal capture rate in the patch (energy acquisition relative to cost)

drops to the average capture rate for the habitat as a whole (Charnov 1976).

Since predators (even sapient ones) generally will not know what the exact average capture rate for the environment is, actual behavior is expectd to follow the Margional Value Theorem only very generally, not with mathematical precision. In fact, this is precisely what is observed in test situations (Krebs 1978:43, 45-48).

Ultimately, the consecutive depletion of patches can lead to a situation where, with frequent cropping, all patches come to have the same marginal value, that is, become equally attractive (Krebs 1978:43). Such a condition has interesting implications. With intensive use, differential productivity of patches becomes nonexistent, so that the environment will be foraged in a nonselective fashion.

Foragers that return to some central place are termed "refuging predators" (Morrison 1978). For refuging predators (including human populations), three factors define the distance threshhold of a resource: 1) food item payoff, 2) commuting costs, and 3) search costs (Kelly 1980:79). There are a number of factors that are peculiar to refuging predators. Optimal search time per unit area, holding all other factors constant, should decrease with distance from a central point (Anderson 1978:404), as commuting time increases. Refuging predators must strike a balance between commuting and search costs. In low ET settings, where mobility must be high, the locations of residences will be changed when search and pursuit times outweigh commuting time to a prey location (Kelly 1980:43).

Refuging predators in some circumstances fail to take the closest prey. The reason is that refuging predators increase efficiency by minimizing overlap in areas searched. Overlap is reduced by minimizing the number of turns relative to length of a foraging transect. If the length of a foraging transect (distance between turns) is given by _a_, while the prey detection radius is given by _r_, then search time is minimized by large values of a/r (long transects, few turns, high straight-line distance traveled from base). Commuting time is minimized by small a/r (short transects, many turns, low straight-line distance traveled from base). For refuging predators, the relative importance of search (large a/r) and commuting (low a/r) costs depends on the number of feeding visits that will be made to a patch (Morrison 1978).

For human foragers, the expectation of numerous feeding visits to a patch, or an area, might result in residential relocation. This is most likely to occur for floral resources (Kelly 1980:75), for herds of fauna, or for faunal migration routes. In general, populations using the Forests but resident at lower elevations would be expected to maximize a/r, that is, to minimize search time by long transects with few turns, so that searching overlap is minimized. Populations resident at higher elevations should behave in the direction of minimizing a/r (minimizing commuting distance).

There is an additional factor suggesting behavior which lower a/r among populations resident at high elevations. If high elevation residence occurs when food density is high (expectation of numerous feeding visits), this would favor transferring search toward shorter distances where transportation cost are lower, and thus reducing the foraging area (Anderson 1978:404).

The settlements of human foragers will be situated in respect to resources that are 1) secure, 2) frequently used (e.g., water), 3) less mobile, 4) denser, and 5) less clustered. Longer trips will be made to more clustered resources, to yield a larger return per trip (Jochim 1976:50-63).

## Prey Characteristics and Behavior

Jochim (1976:23) suggests that, for hunter-gatherers, the main factors determining prey selection are: weight, density, aggregation size, mobility, fat content, and nonfood yields. It is doubtful if the last item would be a relevant factor including inducing predators to undertake the extra commuting and transport costs of high altitude hunting.

Extensive logistical mobility becomes economical only when a resource has a high payoff per food item. In general, faunal resources would be ranked more highly in this regard than floral resources (Kelly 1980:79), while within the set of faunal resources, the factors elucidated by Jochim would be relevant.

These points suggest that separate trips to high elevations to collect most types of food plants would be uneconomical in terms of commuting and transport costs. In general, plant collecting at high elevations should be done only 1) by populations resident at high elevations, 2) within the context of hunting trips, or 3) for exceptional high energy resources such as pinyon nuts. Many of the floral resources available up to 8000 feet are also available at lower elevations (Plog 1983b).

For faunal resources, many species of low body weight and fat content (such as rabbits), which occur at low elevations, could not be economically obtained by travel to higher elevations. In addition, small animals taken by traps or nets can be easily transported to the residence for butchering, so that no archeological record is created at the place of procurement.

This leaves four major animal species that might be economically taken at high elevations: turkey, mountain sheep, deer, and elk. The following disucssion wil focus on the last two. Turkey will not be discussed here since, at least during much of the Puebloan era, this species was domesticated. Mountain sheep occupy rough, inaccesible terrain. They favor cliffs, crags, and rocky areas adjacent to suitable feeding sites (grass and browse plants) (Findley et. al. 1975). Although they did not usually form a major component of prehistoric diets, they probably would have been taken whenever encountered, and were in some areas quite important.

Deer were undoubtedly the major resource exploited at high elevations. They are comparatively high in weight, density, aggregation size, and fat content, and low in mobility. Elk do not occur in large enough numbers to have provided a major subsistence resource, but since much of their territorial behavior overlaps with that of deer, they would probably have been taken at some relatively constant rate without added search costs.

## Deer Behavior

Patterns of deer movement, herding behavior, and overall behavior are strongly patterned and predictable. In Arizona and New Mexico, the higher elevation mule deer herd generally ranges from mixed conifer down to the lower pinyon-juniper woodlands. Deer will move to lower elevations in winter when snow reduces food supply, although no movement may occur when snow-

fall is light. When moving from one area to another, mule deer prefer to migrate along buttes, escarpments, and wooded stream bottoms. Daily and seasonal movements can vary considerably, depending on food, water, and shelter. However, unless there is snow cover, all requirements can be met within a few square kilometers. In northern Arizona and New Mexico, when migration is necessary, entire herds will follow established seasonal migration patterns, with older individuals seeking out the same general areas of summer and winter range. Yearlings, though, will wander and seek new territory in summer. Herd banding during movement is quite strong. On a daily level, activities occur mainly in the early morning and evening, with little in between. Mule deer feed in relatively open areas, but usually in reduced light.

The winter diet consists predominantly of browse, late fall dependence is on mast, the summer diet is herbaceous. Fawning centers on the first of July in the northern Southwest. Late summer and fall are the best times nutritionally for deer, due to summer rains and lower nutritional requirements (no carrying fawns, no growing antlers, little movement). Stress increases late in the fall with the start of the breeding season. Winter and spring are the worst seasons, with increased mortality. This is due to the stresses of pregnancy, antler growth, cold resistance, travel, poorer nutrition, and shedding the winter coat.

Herbage, the main summer diet, drops dramatically with the existence of overstory. Aspen, though, is excellent browse for deer. Wet meadows (cienagas) near streams or springs provide good forage conditions. Riparian zones have many useable plant species. Gambel's oak provides food in the form of leaves, woody stems, and acorns, and is also a bedding area. This is possibly the single most important plant species for mule deer.

Early winter tends to be spent under conifers, where the snow is lowest and softest. The conifer overstory provides a radiation shield for cold protection, as well as storm protection. During periods of strong winds, mule deer are found below the crests of hills and in densely crowned forests.

In the Arizona chaparral habitat, including the western sector around Prescott, desert mule deer are year-long residents. In the Sonoran Desert, they are most abundant on upper bajadas in desert shrub vegetation, near or in ecotones of desert shrub and chaparral, grassland, or woodland (Hungerford, Burke, and Ffolliot 1981; Patton 1981; Geist 1981; Urness 1981; Wallmo and Regelin 1981).

## Elk Behavior

Elk behavior, like that of deer, is highly predictable. There is a strong tendency to return to the same ranges each year. Elk follow the same migration routes, and remain in relatively stable social groups year after year. Large aggregations of elk were observed in New Mexico in the 19th century. One such observation recorded approximately 2000 animals.

Elk prefer open, grassland vegetation for feeding. They are strongly ecotonal, being adapted to both forests and plains. Major behavioral characteristics include movement toward open landscapes, grazing, and occupation of ecotones. They will seek out dense conifer forests to reduce heat loss, and for security. Also for security, they tend to group when feeding.

Some elk herds will move in winter, while others, if conditions are right, will not. Vertical, seasonal migration is characteristic of elk in mountainous regions. During summer, elk disperse in irregular groups, and may be found in almost all suitable habitats at all elevations.

Elk prefer to graze, but browse is a large portion of the diet in many herds. Shrubs will be used where grasses are less available. Conifers will occasionally form part of the diet. As most grasses dry and mature in summer, elk will shift more to forbs and woody plant twigs and leaves. In late summer and fall, when green herbaceous forage is no longer available, they will shift to dried grass and browse.

Elk most freqnely use slopes between 15 and 30%. Above slopes of 40 to 50% there is little use. They are known to use ridge tops, spur ridges, and drainage bottoms. Elk prefer upper slopes regardless of season. South-facing slopes are preferred in winter, but are seldom selected in summer.

Elk will seek shelter in high winds. During summer, the upland forests provide shade. Older, more developed forest stands without lower branches permit wind cooling. Security cover and forage are both important, so elk prefer ecotones between forest and grassland. On ponderosa pine vegetation, elk use is greater where juniper is present, that is, in mixed conifer. There is a high correlation betwwen areas of herbage and elk use.

Elk and mule deer are generally not in competition during the summer, since they favor different habitats. They may be found in the same habitat during winter (Bryant and Maser 1982; Geist 1982; Adams 1982; Nelson and Leege 1982; Skoulin 1982; Nelson 1982).

## PREDICTING ACTIVITIES AND THEIR LOCATIONS

The observations and propositions delineated in the preceding pages provide a theoretical basis both for understanding much of what we already know about the distribution of upland hunting and gathering activities, as well as for predicting activities and their locations.

### Zonal Characteristics

There are a number of factors which suggest that, at all times, the pinyon-juniper zone would have been a preferable foraging location for human populations than the Transition and Canadian zones. The characteristics of higher elevations that make them less attractive are: 1) higher primary biomass, shorter growing seasons, and lower net primary production, leading to decreased availability and accessibility of edible floral and faunal resources; 2) the nutritional value of edible floral resources is low; 3) for refuging predators, travel to higher elevations will always increase commuting and transport costs, and decrease optimal search time; 4) favored animal species, such as deer and elk, usually winter in lower elevations.

These factors indicate that, as a rule, a higher density of archeological remains resulting from hunting and gathering activities can be expected in pinyonjuniper than in higher vegetation types, and that site density will _in general_ decrease with increasing elevation. The lower overall productivity of higher zones for human populations requires high mobility when such zones are used. When residence (defined as occupation by both the producers

and consumers of a human group) occurs at higher elvations, one of two possibilities will ensue: 1) residence will be short, with the population quickly returning to lower elevations; or 2) residence will be short, with the population quickly relocating elsewhere in the same kind of habitat.

Under the latter possibility, the presence of a residential site (however this is perceived by the archeologist) will indicate the probability of other such sites in the general area. Under either possibility, the archeological record which results will be light and ephemeral, except where returns are made at intervals to the same residential location.

Residences, when they do occur at higher elevations (above the juniper belt), will be found more often in pinyon-juniper than in mixed conifer, and will decrease in number, size, and debris density with elevation. It is doubtful whether hunter-gatherer settlements will very often occur much above the mixed conifer zone.

It is to be expected that high elevation hunter-gatherer settlements would be situated with respect to: with water shelter resource diversity floral resources, especially seed-bearing grasses and pinyon nuts.

## Predator Behavior

Human foragers at high elevations, under hypothetical "average" or "normal" conditions, would preferentially use the richest resource patches, in which they would forage for the optimum resources until the productivity of the patch for these resources declines excessively. In the upper portion of the Upper Sonoran zone the optimum plant resources might be seed bearing grasses, pinyon, and perhaps oak. Deer would be the preferred animal species, along with elk if their winter migrations carry them so low. Rabbits and other small fauna would be used by populations resident in or near this zone, but would not be taken by populations with substantial commuting and and transport costs. In the Transition and Canadian zones no plant resources are optimal, while desireable faunal species would include deer, elk, mountain sheep, and turkey.

Under conditions of stress (low resource density relative to population) foragers would be expected to make more use of less desireable prey, and of high elevations. In such a situation, as the richest resource patches are depleted of the optimal prey, foraging will take place in an increasingly non-selective manner, in regard to both species and patch use.

Refuging predators resident at lower elevations would be expected to minimize search costs by long foraging trips with few turns, resulting in a high straightline distance traveled from base. Counteracting this trend is the fact that optimal search time decreases with distance from base. These propositions by themselves do little to assist in predicting high altitude site locations, but they do help to clarify a contrasting situation: when populations reside at higher elevations they will reduce commuting and transport costs by overlapping search areas so as to travel only short distances from base. This suggests that where high elevation residences are found, it is to be expected that resource extraction activities were carried out in the general vicinity. Archeological survey strategies should be gauged accordingly.

## Prey Characteristics and Behavior

Deer and elk are two species that would have been included in the high elevation

optimum breadth diet. The behavior of both is highly patterned and predictable, as should be the archeological record that results from their exploitation.

Deer would be taken in lower elevations throughout the year. They can be found in areas with browse, in shrub or woodland vegetation that provides bedding security, and most especially in ecotonal situations. They would be taken at high elevations in summer. Their primary locations would then be: 1) in open areas of browse, especially Gambel's oak and aspen; 2) in wet meadows near streams and springs; 3) in riparian zones; 4) during windstorms below crests of hills and in densely crowned forests; 5) in early winter under conifers; 6) at all times in the ecotones between coniferous vegetation and more open areas.

Deer will also be found, at all elevations, on buttes and escarpments, and in wooded stream bottoms. They may be found throughout coniferous forest, but theit locations in forest are not easily predictable.

In the lower Sonoran zone, mule deer will be found most abundantly on upper bajadas in desert shrub vegetation, near or in ecotones of desert shrub and chaparral, grassland, or woodland.

Elk, during the winter, are found at lower elevations, below the snow belt. They will occur in open, grassy areas and along south facing slopes.

In summer elk will be found througout higher elevations. Major predictable locations include: 1) open, grassy, mountain meadows; 2) areas of browse; 3) forest/grassland ecotones; 4) in forest (especially older, matrue stands) adjacent to open, grassy meadows; 5) on upper slopes (except those which face south) of between 15 and 30% (less frequently up to 50%); 6) on ridge tops and spur ridges, and in drainage bottoms; 7) in mixed conifer.

Any model predicting locations for high elevation archeological survey should include the kinds of habitats outlined in these pages.

## Concluding Remarks

The efficacy of predictive models for reducing the costs of archeological survey is at least partly tied to the question of whether human activities are clustered, or whether they are spread evenly or randomly throughout the environment. This section may shed some light on that question. High altitude resource procurement, espeially of elk and deer, is for the most part highly patterned and predictable. The tendency of optimal foragers to select high yielding foods, to forage preferentially in rich resource patches, and to engage in patterned commuting and search strategies, coupled with the predictable behavior of deer and elk, presents us with a highly favorable situation for the production of clustered, patterned archeological remains. Yet some caution is in order, for there are countervailing tendencies that may serve to randomize the distribution of archeological remains.

One of these countervailing tendencies is the fact that environments change. Climate varies, drainages change, erosion and filling are inevitable. Fires create open habitats that are in turn ultimately refilled by forest through ecological succession. The result is that, although there may be a limited number of optimum habitats for hunting deer and elk, through time many such locations may appear and disappear. This can only render more complicated the task of developing predictive models.

A second countervailing factor is variation in human procurement strategies. We would expect huntergatherers under "average" or "normal" conditions to forage for optimal resources in rich resource patches. But under stress, where resource availability is low relative to population, two things may happen: first, the optimal resource set would be exceeded, so that more species would be included. And second, rich resource patches will have their productivity reduced to that of the habitat as a whole, so that the spatial distribution of foraging activities becomes more highly dispersed.

Thus, variation in both environments and human foraging strategies can introduce considerable variation into the patterned distribution of archeological materials.

Where optimal foraging and patterned prey behavior would produce a situation of clustered archeological remains, environmental and foraging variability will produce just the opposite. This can throw a substantial wrench into the machinery of any predictive model. The obvious lesson to be learned is that predictive modeling is a difficult, ambiguous undertaking. Equally important, it may well be, as in a situation where stress causes optimal foraging to break down, that the archeological remains that are not clustered and easily predicted may reflect a different kind of behavior from those that are. If this is the case, then it is incumbent upon us to develop models and survey strategies that do not systematically preclude the discovery and recording of such remains.

# AGRICULTURE IN THE SOUTHWEST

Linda S. Cordell and Steadman Upham

## INTRODUCTION

Throughout nearly the whole of human history, human groups have made their living by extracting critical edible resources directly from the natural environment. This strategy is generally referred to in a generic sense as hunting and gathering, although a variety of more specific terminology has arisen to describe variation in the extractive and logistical properties of groups involved in this kind of an adaptation. On a world wide basis, a major change occurred in human subsistence strategies about 10,000 years ago. Instead of extracting natural edible resources directly from the environment, human groups began to manipulate the reproductive capacities of certain plants and animals. This process, domestication, lead to significant changes in the pattern of human adaptation. As yet, the theory of agricultural adaptations is not well developed. Domestication, and the eventual reliance on domestic crops had dramatic effects on human social organization, the relationships between human groups, and the way human groups perceived and used the landscape. The appropriate body of theory necessary to deal with these changes cannot draw on subsidiary disciplines such as animal ecology, and other more or less developed theoretical models relevant to studies of hunters and gatherers. By and large, the information we have is descriptive.

In the New World, the process of domestication has been intensively studied. The consequences of domestication, particularly as they relate to changes in the pattern of land use and the structure and organization of human populations, are poorly understood. In this section, are addressed what we believe to be the most important variables that pertain to these changes and we focus on those aspects of an agricultural adaptation that are predictable and expectable outcomes of decisions to utilize domesticated plant resources. The focus is on the American Southwest.

The adoption of agriculture occurred relatively late in the prehistory of the Southwest and agriculture was always imbedded within strategies that maintained, more or less, investments in hunting and gathering. We see a critical need to develop theory that addresses the oscillation between hunting and gathering and various intensities of agriculture. The theories must also consider important characteristics of a primary reliance on agriculture in the Southwest. We consider the following to be a begining in identifying the essential elements of theories that can account for variation in prehistoric agriculture in the Southwest.

Despite widely held notions that the environments of the Southwest are unfavorable, risky, and marginal for agriculture, settings appropriate for agriculture are in fact found throughout the area. A number of studies have specified the relevant attributes of Puebloan agriculture (Hack 1942, Plog 1978, Ford 1972, Cordell and Earls 1983, Sullivan 1982). These attributes are discussed in detail below, however, it is notable that the pertinent attributes of land, water, etc., are not localized but exist across wide regions (Upham 1982; Cordell and Earls 1983). In other words, the environment is not necessarily a factor limiting agricultural

production; it appears that agriculture can be practiced in even the most extreme settings. Agriculture was not, of course, practiced everywhere, and theory must aim at explaining the changing dynamic governing the variable use in locations over time.

The development of such a theory or theories should incorporate basic information that today is unavailable. For example, there are no analogs for all the varieties of prehistoric crops (especially maize) cultivated in the Southwest. Consequently, we do not know the specific edaphic and climatic requirements for them. General models of plant growth consider soil nutrients the key limiting factor in crop production, and except for some preliminary work (Noy-Meier 1973), there are no ecological models of plant growth that pertain to situations, like those in the Southwest, where water can be the most critical factor.

In comparison to theoretical statements about hunters and gatherers, situations involving agricultural populations depend upon environmental packing and density dependent relationships. Much of our discussion is concerned with issues that arise in density dependent situations, when homoeostatic regulating processes cannot be assumed. Consequently, we require information about population growth, the distributions and spacing of populations, and changes in the demographic structure of human groups. At the very least, reliable estimates of population numbers are essential; however, we recognize that there are no methods currently available for estimating prehistoric population that are in any sense accurate or precise.

In spite of the difficulties discussed above, it is profitable to proceed with a trial formulation toward theory development. We believe the most critical dimension conditioning the range of the actual or potential responses of agricultural systems is demography. Our point of departure, however, is a consideration of the static relationships among those variables we believe are essential to generating predictive models relating to agriculture subsistence. These variables include considerations of the domestic crops, those native species that may have been cultivated or encouraged, and the environment. Once these static relationships have been discussed, we introduce the factors that are deemed critical in understanding the dynamics of agricultural systems. In order to predict the locations of agricultural activities and settlements, and the subsidiary activities of agricultural groups, one must understand the interplay between those variables we will define, the way they are employed in systemic context, and the way that they change through time.

## VARIABLES

### Crops

Our consideration of crops involves the traditional southwestern cultigens of maize, beans and squash as well as various native species. Maize, beans, and squash were introduced from Mesoamerica. In contrast to most discussion of southwestern cultigens, we also consider native Southwestern species that may have been domesticated, cultivated, aided and/or systematically used. Native species are rarely considered in discussions of southwestern agriculture, but they have major import for activity patterning and settlement distribution.

Maize was the staple crop for agriculturalists in the Southwest. A significant

characteristic of maize is its genetic diversity and plasticity. As noted above, the specific requirements of the varieties that were cultivated prehistorically are not known, however, there is information available on the moisture, growing season length, and some edaphic requirements of existing varieties. In the Southwest, moisture is the limiting factor for maize development. It is not only the amount of moisture that is crucial but the timing of moisture application as well. Experimental data (Classen and Shaw 1970; Denmeade and Shaw 1960), derived from modern hybrid maize, show that maize requires 50 cm of moisture during its growing season, excluding its germination period. Sufficient soil moisture must be available for seeds to gerninate. This is particularly problematical in the Southwest where the spring season is largely without rainfall. To compensate for rainfall shortages during this critical germination period, modern Puebloan groups rely on melting snow pack. This practice requires warm spring temperatures and soil conditions that are conducive to moisture retention. During the growing season, additional moisture is most critical during the tasseling/silking period (approximately 60 days after germination). Water deficits at this time will decrease yields by 75% or more. Although water itself is critical, torrential thunder storms, that characterize summer precipitation in the Southwest, can be devastating. Additional moisture is needed to bring crops to full development toward the end of the growing season (about 120 days), however, insufficient amounts at this time rarely reduces the yield by more than about 20%.

In addition to, and interacting with available soil moisture, is the length of the growing season. In general, a growing season length of 120 days is considered necessary. As Hack (1942) pointed out, under conditions of moisture deficiency, a longer growing season may be required. In fact, a 120 day season is available over much of the Southwest with 140 days not uncommon. There are situations in which archaeological data indicate that corn was grown in locations that today have a growing season length that is highly variable and often only 90 to 100 days.

Edaphic factors relate to both soil conditions (depth, friability, drainage, etc.) and to soil nutrients. Very little is known about the specific edaphic requirements of prehistoric varieties of maize. However, as noted, soils must be capable of retaining moisture while at the same time resisting waterlogging and flooding. Maize does require abundant nitrogen as a soil nutrient, and the plant frequently depletes nitrogen from fields. A widely held anthropological myth describes the practice among southwestern peoples of planting beans in the same field as maize. The bacteria in the leguminous bean roots enhances the nitrogen content of the soil. In fact, although peoples throughout Mesoamerican do plant beans and corn in the same fields, and in the same hills within those fields, the practice of intercropping the two plants is infrequently reported in the ethnographic literature of the Southwest.

Beans were also introduced into the Southwest from Mesoamerican, with the possible exception of the scarlet runner bean, which may be native to areas of northwestern Mexico and southern Arizona (Ford 1981). Far less information has been compiled about the varieties and distribution of beans in the Southwest than for maize. Common beans (Phaseolus vulgarus) are the most widespread species planted in the area. Scarlet runner beans (Phaseolus sp.)

appear in the archaeological record of the Hohokam and Kayenta areas. The incidence of tepary beans in Hohokam contexts has recently been questioned (Gasser 1981).

Once again there is a lack of information about the specific requirements of beans, however, generally beans have a shorter growing season than maize, prefer well drained soils and are more photosensitive during germination than maize. Beans cannot tolerate poorly drained soils and water logging can affect crop vitality and viability. We would suggest that the photosensitive properties of beans would require careful selection of fields, with particular attention to aspect.

Squash (Cucurbita sp.), in contrast to beans, is remarkably productive with high water inputs. In most cases, the plant is hardier than either maize or beans. There are numerous varieties of squash that were planted prehistorically and unfortunately, there is little information on their specific requirements. In addition to the cultivated squash that was derived from Mesoamerica, there are varieties of so-called inedible squash that are native to the Southwest (e.g. Cucurbita feotidissma). These plants and the domestic varieties, however, contain edible seeds that are a rich nutritional source. Cotton (Gossypium hirsutum) is reported as a relatively early cultigen in the Hohokam area. Cotton is well documented for the Kayenta area and some adjacent areas of the Colorado Plateaus at about A.D. 700 (Ford 1982; Gasser 1982). Given the controversies surrounding the Hohokam chronology (Schiffer 1982), it is possible that the well dated contexts on the plateau are a better indication of its first appearance in the Hohokam area. Further, cotton was reported growing in extensive fields during the early contact period in the region surrounding the Hopi Mesas (Espejo 1582). Cotton products (e.g. textiles) were widely traded in the early historic period and cotton mantas were paid in tribute (made as gifts) to the Spanish.

Normally cotton is thought of as a product from which textiles and other woven goods can be made, however, the nutrient value of cotton seeds should not be underestimated. The value of cotton as a foodstuff has been borne out by coprolite studies that reveal a high incidence of cotton seeds in human feces (Gasser 1979; Bohrer 1971).

Temperature regimes and a long growing season are critical for the successful cultivation of cotton. In addition, the plant requires abundant moisture during the growing season and is known to be subject to damage by insect infestation. The prehistoric distribution of cotton in the Southwest shows that it was ubiquitous given that a sufficiently long growing season was available. Cotton was grown in valley settings throughout the Colorado Plateaus, along the Rio Grande, and, of course, in the Lower Sonoran desert.

## Facilities

Agriculture using the above crops can be practiced at varying levels of intensity. Frequently, the technology of crop production at a low level of intensity is not expected to leave visible archeological remains. For example, the Apache casually utilized maize without investing labor in the construction of agricultural features and without establishing permanent settlements. As agriculture becomes more important and as the reliability of crop production becomes more critical, various kinds of technological facilities were used to enhance productivity. We consider the technology of agricultural production to include knowledge relevant to manipulating

plants and habitat areas, technical skills necessary for cultivation, the construction of facilities, and the facilities themselves. Knowledge can be viewed as a non-material dimension of an agricultural strategy that societies must preserve and transmit transgenerationally. We suggest that such knowledge may frequently involve some specialization and institutionalized organizations for the perpetuation of that knowledge. One of the most visible aspects of an agricultural adaptation are water and soil control features that become prevalent as dependence on cultigens increases.

In the northern Southwest, the presence of water and soil control features is common after A.D. 900. These features include irrigation canals and associated features such as diversion dams and head gates, terracing, waffle gardens, check dams and linear border gardens with and without gravel mulch. These features singly and in combination occur in appropriate topographic settings throughout the Southwest, regardless of culture area. We have listed these features in the order of decreasing labor investment. Although few experimental studies are available, those that exist indicate that aside from irrigation canals actual labor requirements were minimal in the construction phase. Labor to maintain all kinds of features, however, may have been substantial.

It is clear that certain types of features are suited to particular kinds of terrain and to the solution of specific problems. These features are found alone or in combination throughout the Southwest. Irrigation systems require a permanent water source, low gradients, and serve to increase the moisture available to field areas. Terrace systems are best suited to hill slopes with gradients of 15 degrees or less and function to slow surface runoff, enhance moisture penetration to root level and inhibit erosion. Waffle gardens serve the same functions as terrace systems and, in addition, can be used in conjunction with irrigation. In many cases, particularly in the southern deserts, waffle gardens are situated on the margins of major rivers or arroyos. In these latter cases, one of the major functions of waffle gardens is to trap alluvium during annual flooding. Check dams occur singly or in series across arroyos. They serve to channel surface runoff to adjacent fields. These features also inhibit erosion, allow maximum use of available water and enhance soil moisture. Linear border systems occur on slopes or benches and are often constructed to clear surface cobbles from field areas. In many ways, linear border systems function in the same manner as terraces, but with less labor investment. Gravel mulch fields, which consists of a layer of fist size and smaller gravel on the surface of field areas demarked by linear borders, is reported for specific tributaries of the northern Rio Grande. They are abundant in locations where the growing season is highly variable and frequently less than 120 days. As with any mulch, gravel retards evaporation of soil moisture. However, as a good conductor of heat it also serves to increase surficial soil temperature, moderate soil temperature variation and thus extend the length of the growing season at surface level (Cordell and Earls 1983).

Agricultural technology involves selecting specific field locations, for example, for aspect or soil characteristics. In addition, the technology includes the use of diverse cropping strategies such as intercropping, monocropping, planting in different topographic settings, fertilizing and multiple plantings during the growing season. While much is known about the

structure and organization of agricultural villages, little has been reported about the specific criteria involved in this kind of decision making. Further, in the absence of specifically designed field projects (e.g. transect pollen sampling), the locations of many if not most field areas are unknown.

## Native Species

In the context of crop production, various species of plants native to the Southwest may have been cultivated, aided or enhanced, or intensively collected. Certainly, the manipulation of these species as evidenced in the archaeological record differs from the way in which hunter-gatherers utilized the same plants. There is some evidence which suggests that certain native species, particularly *Agave parrii*, Catclaw and Devil's claw cactus may have been domesticated in the Southwest (Minnis and Plog 1979; Ford 1982). One of the strongest indicators for this inference is the location of species outside of their native ranges and their proximity to locations of past human settlement.

The growth of some native plants such as native barley, mesquite, and Indian rice grass may have been enhanced by prunning, watering, burning or other methods. The relationship between enhancing productivity and intensive utilization can be small for some species, particularly those whose productivity is increased through harvest.

With the use of cultigens, some species were encouraged or tolerated in field settings. The archaeological data indicate that these commensals may have been treated in much the same way as domestic plants. These plants do not form a significant part of the archaeological record of hunting and gathering populations in the Southwest, but increase markedly with the inception of agriculture. These species are predominately of the weedy variety and include chenopodium, amaranth, pig weed and tansy mustard.

Finally, the collection of wild plants continued to constitute an important part of the subsistence of southwestern agriculturalists. Cactus fruits were collected, and in the case of saguaro involved a sophisticated technology (Castetter and Bell 1942; Goodyear 1975). The harvesting of pinyon nuts is not only an important activity in agricultural groups but also has structural implications for the formation of logistical groups and the establishment of special residential sites. Black walnut and acorn procurement may have been locally important as well. Finally, collection of juniper berries and the fruits of various understory plants such as serviceberry, choke cherry, rhus, hackberry and others continued to form an important part of agriculturalists' subsistence. Needless to say, archeologists need to be attentive to the distribution and abundance of these plants and to understand the timing of their availability. These relationships have important implications for the structure of task group organization.

One very important consideration relating to agriculturalists and their use of resources is that the preparation and maintenance of agricultural fields creates additional and critically important habitat areas. As noted, the commensal plants form an important part of the subsistence economy and most likely grew alongside domesticates in fields and were probably tolerated in the disturbed ground within and between villages. In addition, game animals continue to constitute a key dietary ingredient in the overall subsistence pattern. Fields provide an increased prime habitat

area for certain animal species such as rabbits, mule deer and avifauna. In some cases rabbits may have been "cropped" from agricultural field areas providing a ready source of protein. Birds that previously may have required special logistical hunting trips (migratory water fowl, raptors, etc.) are attracted to fields (Emslie 1981) thereby decreasing the amount of labor required to acquire them.

## ENVIRONMENT

We consider at least one aspect of natural environmental conditions crucial to an understanding of the differential situations leading to the adoption of agriculture. We accept the general anthropological notions that any agricultural activity involves more labor investment than hunting and gathering under conditions of unrestricted mobility. With reduced mobility, agriculture becomes a potential solution to two very different constraints. Domestic crops may provide a surplus that can partially resolve an "over-wintering" problem. By overwintering we mean the acquisition of sufficient storable foods to sustain the population when plants are dormant and when densitydependent factors have restricted people's access to either late fall or winter hunting territories or to areas with a longer growing season. A convenient measure of the length of the growing season, and therefore an indication of the potential overwintering problem, is provided by effective temperature (ET) (Cordell 1979; Binford 1980). Empirically, at an ET of 14 degrees centigrade or less over-wintering becomes a potential problem.

Over approximately the northern one half of the Southwest ET does range below 14 degrees. Over the rest of the Southwest, ET values are at 14 degrees and above. We suggest that in these latter areas agriculture was a strategy adopted to solve different density-dependent problems. In areas where ET values are 14 degrees or above, agriculture can serve as a buffer against environmental risk when mobility is restricted. In this case, agriculture provides an additional food source and is most likely to have been adopted to buffer the lean time of the year. The lean time for southwestern hunting and gathering populations in the southern Southwest was the late spring when most winter stores had been exhausted and just before the fruiting season of wild plants. This suggests that agriculture in the southern Southwest provided edible green corn whereas in the north, mature harvests were being utilized. This dichotomy may explain major differences in the subsistence and settlement systems of the Hohokam and Patayan on the one hand and the Mogollon and the Anasazi on the other since ET differs markedly between the two pairs of groups.

Once agriculture has become established as part of the subsistence economy, environmental variables that are important to successful crop production must be considered. The stable environmental variables that we believe are of relevance are attributes of topography; slope, elevation, landform, aspect, soils, and drainage. We have discussed some of these attributes above. Some of the other attributes are useful guides to other environmental factors or conditions that are important to plant growth. Thus, elevation is a key to precipitation and temperature; landform is a key to soil development and, in some cases, soil type.

Those environmental processes which vary in either high or low frequency (Dean this vol.), are also important for agriculture. The processes include precipitation, erosion, wind, temperature, and variation in

water tables. For agriculture, significant variation in the periodicity and quantity of precipitation can have major effects. As we pointed out above, it is necessary to include the accumulation of snow in considering precipitation, because of the critical importance of snow in effecting moisture available for seed germination. Wind can effect agricultural production in a variety of ways. Strong winds in the spring can seriously damage young plants. Wind also increases the rate of evaporation which diminishes available supplies of water at ground level. Wind is also a significant factor in creating erosional patterns, the results of which, deflation and aggradation, can have varying effects on agricultural fields. In addition, wind often is combined with other environmental processes (e.g., snow or rain) and the consequences can either be beneficial or damaging to agricultural crops.

Variation in ground water tables has probably been significant in the past, and this variation conditions the amount of water available for plant use. Studies of prehistoric agriculture have shown that seeps, springs, permanent and intermittent streams were used as sources of water for crops, often in combination with the kinds of facilities that we have discussed above. Understanding the structure of various kinds of agricultural systems requires information about potential ground water and runoff sources.

An environmental variable that is often neglected in discussions of prehistoric agriculture is a category that includes insects, mammals and birds that adversely affect crops. Some of these species, if controlled, can have a positive value for human groups. We mentioned the "cropping" of rabbits and hunting of birds in field areas in our discussion above. It is important to recognize however, that rabbits, mule deer, grasshoppers and the like can completely devastate crops in a very short period of time.

All of the above factors concern and effect agricultural production. Of prime importance too is that agriculture itself, and particularly the concomitant seasonal or year round sedentism has major implications for the structuring of other human activities. We discuss some of the consequences of agriculture in the next section.

## CHANGES IN PROCUREMENT STRATEGIES

In the Southwest, as in many parts of the New World, the absence of domestic animals dictated the continued importance of hunting throughout the prehistoric period. Once groups adopted agriculture, however, their reduced mobility required changes in the organization of hunting. In general, a considerable amount of ethnographic work (Saffirio and Scaglion 1982) demonstrates that as groups become more sedentary, hunting activities become more logistically organized. That is, groups of individuals travel further to procure some kinds of game. Logistic hunting of this sort requires considerable planning and often involves covering truly great distances. For example, in the early historic period, hunting parties from the Pueblo of Laguna travelled more than 70 miles from the village and the Taos ventured far out onto the Great Plains. This, of course, is balanced by the field hunting of smaller size animals.

Hunting activities, particularly logistic hunting, must be scheduled by groups in such a way that it does not conflict with the peak demands for labor during the agricultural cycle. It is likely that the scheduling of activities, as they become

more complex, become a function of "specialists" controlling calendrical knowledge and information regarding planting and harvesting cycles. Other specialists were probably involved in acquiring information about the location of game. This implies regularized interaction with other groups of people.

Scheduled use of the landscape (the sustaining areas of agricultural societies) among more or less sedentary communities must involve the resolution of potential conflicts over resource acquisition. The implication of this for social and political organization, is minimally, to require a more formalized decision making structure. The need to reschedule activities may also condition a different use of resoruces in that some kinds of resources may be "banked" for the short or long term. We discuss this consequence of scheduling in more detail below.

The change from a hunting and gathering to an agricultural adaptation requires a number of significant changes in resource procurement. Some new kinds of resources must be acquired, such as clay for ceramic containers. Other resources were part of huntinggathering economies (e.g. fuel wood) but require different behaviors for their acquisition. Again, rescheduling of activities is entailed in procuring these resources.

At present, we have little descriptive information and virtually no theory that relates to changes in resource procurement with sedentism. For example, it is unclear under what conditions sedentary groups obtain lithic resources though logistic trips, logistic trips imbedded in other activities (e.g. hunting), exchange, or whether people "make-do" with local materials. Clearly, methods of obtaining lithic resources follow a changing trajectory over time as groups become more or less sedentary and as interactions with other groups become more or less formalized. When people are highly mobile, resource procurement may appear relatively easy, however, with sedentism obtaining basic materials becomes problematical and groups must adopt appropriate strategies to obtain what they need. In the case of lithic resources, three primary alternatives are available to sedentary groups: use of local materials, the acquisition of non-local materials through direct procurement, and acquisition of non-local materials through exchange. The latter two options may imply organizational specialization.

Given relatively large groups of people and the differential scheduling of activities and their organization, information must be controlled and disseminated systematically. This virtually ensures the presence of special mechanisms for marking information and generally includes means of socially distinguishing individuals who coordinate information. Among the Pueblo, this kind of information is symboled by the use of objects made from exotic pigments and minerals that are, in many cases, acquired at considerable distances from the village. Those individuals who coordinate information, especially information relating to scheduled use of the general landscape, must interact with each other in rather formal ways. In performing these roles, these individuals acquire status which is also socially marked. The specific markers may involve the symbols mentioned above as well as privileged access to specially produced craft items.

## CONSEQUENCES OF AGRICULTURE AND SEDENTISM

The transition from hunting and gathering to agriculture entails a number of imme-

diate consequences. Although we briefly discuss these here, some of these consequences have ramifying effects and are treated in greater detail below.

One of the most visible changes apparent archeologically is the construction of storage facilities. These might include pits, ceramic containers, small rooms or Kayentastyle graineries. We would suggest that the particular kinds of facilities constructed are related to two dimensions of variability conditioned by population size. One dimension, already discussed, has to do with whether storage is serving an overwintering function or goods are being stored for the few weeks of lean times in the early spring. In the first case, we would expect greater quantities of food to be stored and would suggest construction of larger or more numerous and permanent facilities in areas with effective temperatures below 14 degrees centigrade. In the second case, we expect fewer, smaller and more temporary storage facilities. The second dimension relating to storage has to do with the protection of foodstuffs from rodent predation. The construction and use of facilities, particularly ceramic containers and storage units with sealed floors, guards against rodent and other small mammal intrusion. In general, small mammal pests are more numerous at lower elevations within the Southwest, specifically in areas of the Lower Sonoran deserts. consequently, we would expect a predominance of the specially constructed features in these areas. Another consideration pertains to the infestation of certain classes of insects into stored grain, a particular problem in the northern Southwest. A solution to this problem is to roof and seal storage structures from above. Storage facilities may provide clues to the character of the foods being stored. For example, in the Gallina area, bins on the floors of pithouses are nearly always vented suggesting that plant foods were stored green.

Another of the immediate consequences of agriculture and sedentism is the change in community or village layout. At the outset, the village must incorporate storage facilities into the residential settlement pattern. The specific location of these facilities in the village have direct bearing on the restricted or unrestricted access to stores. In addition, the number and size of the facilities can be a clue to the number of people who inhabited the village and to the length of time that food was being stored. In general, with increased sedentism and increased amounts of storage there is increasing specialization in the use of space.

A major consequence of increased sedentism and a reliance on agriculture was changes in the health of human populations. The information provided by El-Najjar and others (1976, 1982) indicate that overall health of populations declined with the transition to agriculture in the Southwest. Porotic hyperostosis is used as a diagnostic of iron deficiency. This in turn is thought to be caused by a lack of protein in the diet or, in the case of women, by multiple pregnancies. We are aware, however, that porotic hyperostosis may result from a number of different etiologies, including infectious diseases. More coordinated research is required to resolve this problem. There is also the perception that with the transition to agriculture, population size increased markedly. We believe this interpretation may be questioned because it depends in part on more visible archeological remains being associated with more sedentary groups and on erroneous interpretations of reconstructed life

tables. We address these issues in more detail below.

Clearly, with the change to agricultural production there are major changes in the structure of social, political and economic organization. At the most basic level, there is a change in the composition of task groups. Generally this involves a shift from tasks organized along lines of age and sex to family, supra-kin and other more specialized labor units. This reorganization has implications for the way space within communities is used and consequently, for the spatial distribution of features.

The organization of labor, including labor scheduling, assumes increased importance in agricultural societies. Agricultural production requires a relatively massive amount of labor at certain periods of the year. This labor must be recruited on a regular basis. When agricultural production is limited recruitment may occur along kin lines. As agricultural production intensifies this labor must be recruited through specialized mechanisms. In addition, large agricultural communities must undertake a variety of other tasks (construction and repair of facilities, maintenance of agricultural features, preparation of bulk storage, etc.) which are facilitated by a large labor pool. Once labor requirements have exceeded the "familial" level of investment, the prerequisites for stratification exist in that any population will include those individuals or groups who, of necessity, must "sell" their labor for shorter or longer periods of time. In essence, as has been noted (Marx 1898) labor itself becomes a commodity within the general economy.

There is major restructuring of the economic organization of groups involved in agricultural production. At a very basic level, this would involve a change from open access to commodities within the local community to situations in which access is restricted to individual families or kin groups. This is often reflected in architectural plans and village layouts. Eventually, the restriction of access extends to segments of the society as a whole. Under these conditions, access is controlled by socially differentiated individuals or groups. Again, the manifestation of this situation appears in the construction of centralized, specialized storage facilities, banking and tangible remains that may be indicative of "piling behavior." By piling behavior we refer to construction of large, labor intensive projects that are not directly related to subsistence procurement. For example, the construction of Chacoan roads, ashlar veneer masonry, Great Kivas and other public works projects illustrate piling behavior.

The organizational changes discussed above clearly follow along a scale from less to more specialized, less to more regularized and less to more intensive. In our view the trajectory of increasing complexity is directly related to and underlain by demographic processes. These processes include simple alterations in population size, increases and decreases in the number of people locally and regionally and variation in these through time. However, importantly, demographic processes also refer to the distribution and spacing of human poplations and the changes in these through time. At the outset of this discussion we considered certain variables to be in constant relationship with each other. These were treated as "statics." In fact, demographic processes constitute a major conditioning variable that modifies all of the interactions treated above. We therefore

examine demography and demographic processes in detail.

## DEMOGRAPHY

The archaeological literature is filled with assumptions regarding the relationships between subsistence and population size and growth. These include the citation of "magic numbers" for band or tribe size to statements indicating that human populations nearly always increase. In fact, as we have pointed out above, there are no reliable and precise methods available for estimating prehistoric population size from archeological remains, and until these are developed, much of what is said will remain conjectural. With respect to the Southwest, this issue is particularly crucial in regard to changes in population size with the acceptance of agriculture on the one hand and perceptions of population size during other periods of prehistory based on the visibility of archaeological remains.

It is generally assumed, on a world wide basis, that a shift from hunting and gathering to agriculture is motivated by overall population growth and reduced mobility. In part, this perception is derived from some studies of hunter-gatherers which focus on models of homeostatic equilibrium. These models suggest that information structures within hunting-gathering societies are adequate to maintain regional population densities at low and stable levels. Periodic aggregations of bands can serve to "broker" information about resource abundance, distributions, and the presence of other groups. The homeostatic models indicate that if the "signals" are poor, certain population regulating mechanisms (wide birth spacing, infanticide, senilicide, etc.) are activated. Alternatively, hunting-gathering groups "perceiving" the same situation may, in theory, intensify production or adopt a different strategy. Clearly, the problem with these models is that they fail to account for the selection of either option. They do not, in fact, specify conditions under which each "path" is taken. This lapse is especially troubling, because in many "models" the alternative path selected by hunter-gatherers is the adoption of agriculture. Again, it is assumed that population growth in some way "causes" a shift to agriculture.

In fact, it is entirely possible that agriculture may be adopted for other reasons. The lack of appropriate theory in this regard is critical in the Southwest, as it is elsewhere, because empirically, there is very little evidence for marked population increase during the Early or Middle Archaic. A similiar problem exists on the perception of population growth, whether based on osteological or architectural information. For example, Sattenspiel and Harpending (1983) have demonstrated that reconstructed life tables that are interpreted as indicating population growth (or decline) have been misunderstood. They point out that the mean age at death is in fact the reciprocal of the birth rate. Similarly, the perception of growth based on highly visible architectural remains is a potentially biased index. For example, many population reconstructions in the Southwest indicate that the Pueblo II - Pueblo III transition was a period of rapid population growth. It is striking that this period is also characterized by a dramatic increase in the visibility of architectural remains.

Archaeologists have focused on population growth when, in fact, the more important characteristics seems to be population distribution and spacing. We do not intend to

suggest that population growth, as a variable, is unimportant. However, in terms of understanding social responses to the environment, the more critical variables must be those that are related to the way human groups are organized on the landscape.

Rathern than deal with hypothesized human numbers, we believe that the way groups are organized on the landscape is better conceptualized in terms of the notions of density dependence and packing. Density dependence is a relative descriptor of the relationship between organisms and the quantity of resources in their bounded lifespace. Behavior which is not density dependent describes situations in which organisms (or groups) respond directly to the food resources in their environment. Density dependent behavior, on the other hand, indicates that organisms (or groups) are responding to the other organisms or groups in their food resource area. The appropriateness of the concept of density dependence, in dealing with agricultural societies, is one instance in which a notion from rather developed general ecological theory can serve as an aid. By packing, we refer to the quantity of organisms within their bounded lifespace, and is also derived from the same general ecological literature. (Odum 1971)

Slabodkin and Rapoport (1974) have pointed out that there is a series of energetic responses in density dependent situations. These responses are ordered from those that are least costly, from a biological standpoint, to those that directly threaten the genetic viability of the population. Short-term behavioral responses are far less costly than failure to reproduce. We view the adoption of agriculture as a density-dependent behavioral response, and in what follows, we intend our remarks to refer only to the responses of agriculturalists. Examination of a broad range of ethnographic literature indicates that human groups follow a parallel pattern in situations of density dependence. For example, a first order (low cost) response to a perceived lack of food is commonly the cessation of normal sharing activities (Colson 1979, Scudder 1971, and Turnbull 1978). If shortages continue, this is followed by foraging on the landscape, consuming less desirable foraged foods, increased competitive behavior and finally warfare. Naturally, warfare can have significant effects on the human gene pool.

Various levels of competition characterize the range of density dependent responses of agricultural groups. The concept of competition has been dealt with by anthropologists in the past under conditions which emphasize organizational complexity. In discussing the Valley of Mexico, Sanders and others, (Logan and Sanders 1976, Saunders and Webster 1978) have suggested that competition resulting from population growth is a major explanatory variable that can account for the increasingly intensive use of the landscape. In particular, they argue that competition leads to social circumscription (i.e., a decrease in the available arable land), which in turn, results in shortened fallow cycles, the construction of agricultural facilities, etc. They also suggest that without the opportunity for intensifying agricultural production, the entire system would be threatened and collapse.

Likewise, Carneiro (1970) emphasizes a costly response to density dependent factors in citing warfare as the key factor in organizational development and change. While some of these ideas are useful, they are not necessarily appropriate for describing the range of options taken by societies in less restricted circumstances.

We believe that most of the societies we deal with in the prehistory of the Southwest are at both the lower order of restriction and the lower end of the scale of costly response. As we noted above, agricultural societies in the Southwest were always more or less dependent on hunted and/or gathered resources. In the absence of crop failures, local groups might respond to situations of packing first in regard to wild resources. One low level response that occurs is the social establishment and maintenance of "buffer areas" between aggregated groups. Buffer areas are resource procurement zones, in which permanent habitation is precluded, but which may be exploited for wild resources (Cordell 1979, Hickerson 1962, Hunter-Anderson 1981). In general, it is the potential threat of inter-group hostilities that maintains the buffer zone. The establishment and maintenance of these buffer areas has important implications for the spatial distribution of settlements on the landscape.

A relatively low level response to situations of crop failure, or to resource depletion, may be the increased mobility of local groups. Mobility of agricultural groups was probably far more frequent than most archeologists generally acknowledge. The recognition of mobility, and its concomitant, short settlement occupations, has great implications for estimates of regional population sizes and densities based on room or site counts, and on the interpretation of settlement patterns of more or less contemporaneous sites.

From an internal organizational standpoint, density dependent competition in the Southwest also may result in intensified agricultural pursuits, a change in the structure of decision making, an increase in the number of storage facilities, an increase in the amount of long-distance exchange possibly coupled with a change in the direction and orientation of local and supra-local exchange. The options which are, in fact, selected may well depend on the scale of the systems involved. For example, it may be possible to intensify agriculture through the construction of facilites requiring very little labor investment (e.g., grid systems). On the other hand, it may be necessary to greatly increase production to support large aggregated communities. If this is so, only certain kinds of areas, with specific combinations of environmental conditions may be appropriate. For example, areas may be sought which have extensive amounts of arable land, large areas of runoff or permanent water sources that may be diverted for irrigation.

Restriction of access to certain kinds of resources (wild or domestic) is a frequent response to environmental packing. Within the context of agricultural groups, restricted access often entails the requirement of membership in special function sodalities (such as hunting societies) or is mediated through a ritual specialist or organization. Thus, among the Pueblos, religious societies go on retreats, often into resource areas. This activity may be "for the purpose" of refurbishing shrines, however, considerable observation and monitoring of resources accompany these activities. In another vein, the restriction of access can be manifest by various modes of community wide exchange. For example, redistribution systems that have the ostensible function of distributing food during times of need (Ford 1972), often have the effect of concentrating access to these resources in the hands of a few individuals. This kind of system is easily coopted by individuals in order to serve their own social goals. Ethnographi-

cally, redistributive systems are often portrayed as largely altruistic, however, in most of these systems, very little food is actually redistributed, and the persons controlling the redistributive acts may subsidize their own exchange relationships with trade partners among other local groups. Often times, such subsidies take the form of hard goods, as opposed to food, and consequently during times of need, the banked food resources are unavailable. The result is that the cooptation of the redistributive system guarantees that it is underfinanced. In other words, food turned into hard goods which are then used to establish alliance relationships are not available for local consumption.

On a regional basis, the interaction between agricultural settlements organized at a very large scale may affect the ability of communities to relocate. This packing is socially determined and may coincide with situations in which there is an apparent abundance of vacant land. This contrasts in the extreme with situations among hunters and gatherers in which very few individuals may be spatially dispersed over a very wide area, completely using the available landscape to the limits of their technology. In both cases, the landscape is, in essence, full, and the situation would not be recognized archaeologically. In the case of agriculturalists, few alternatives exist to increase their catchment areas. In these kinds of situations, our ability to identify packing must be refined.

In contrast to the situations described immediately above, density dependence may be reflected in the structured use of space among sedentary groups who have been in an area for very long periods of time. In these situations, as noted ethnographic ally, village layouts, certain kinds of structures, and the patterned use of the landscape outside the village may be organized within a strict cosmological or ritual framework and adhere to very specific models (Dogon) which are easily recognized. Great Kivas in the Mogollon area, and the highly arranged aspect of Chacoan sites in the San Juan Basin may well reflect such density dependent behavior. Similarly, outside the village, the maintenance of specific shrines, hunting areas, and the like reflect a patterned and redundant use of logistic sites that is also a concomitant of extreme packing.

Among hunter-gatherers, gauging the density of people and groups on the landscape is generally accomplished through face to face interaction at various scheduled times throughout the year. Among densely packed horticulturalists, these mechanisms are no longer functionally appropriate. Instead, more formal and more abstract mechanisms are required. Hunter-gatherers symbolically and through more overt behavior, demarcate their territories. This however, is usually accomplished through the use of a very few, widely recognized symbolic markers (Weisner 1983, Wobst 1977). In contrast, sedentary agriculturalists use very complex, abstract, and often times the products of labor intensive activities to perform the same function. These symbolic markers, are imbedded in both political and economic processes. This has great implications for the definitions of regional spheres of interaction or alliances among horticultural peoples, a topic that is addressed below.

There is a tendency when populations either increase or decrease to draw conclusions that relate to the last adaptive strategy recognized archeologically. If population increases in an area previously occupied by agriculturalist, the assumption is that the

additional people are being accomodated by that strategy. Similarly, when population declines radically, the presumption is that the area has been abandoned and that groups have either migrated or have suffered some catastrophic fate. Both of these alternatives seem highly unlikely in most instances. One problem is the very perception of population increase and/or decrease. It is probably often the case that groups are constituting themselves differently on the landscape as they move from more labor intensive subsistence strategies to more extensive ones. This kind of reconstitution has been characterized as alternation between resilient and stable-based adaptations (Adams 1980, Green 1983, Plog 1983a, 1983c, Stuart and Gauthier 1982, Upham n.d.). If archaeologists are ever to begin to understand how the structure of locations change through time, it is imperative that the kind of cyclical oscilation between stable and resilient adaptations be understood and criteria developed for their recognition.

We are impressed in reviewing the descriptive archaeological literature of the Southwest to see how frequently large pueblos show what is interpreted as an increase in large mammal hunting at the ena of their occupations. Most recently, this phenomenon has come to general notice in the Binford vs. Schiffer controversy over the interpretation of the Joint Site (Schiffer 1976). As noted, the pattern is nearly ubiquitous, and from our perspective is directly related to the recognition of resilient strategies. What is clear to us is that observations such as these must be incorporated into a general archeological theory of location. In the following section, we address what we believe to be the critical aspects of locational selection for agricultural groups.

## SETTLEMENT

Archeologists do not have a single theory of settlement or of regions. The way in which regions are defined depends very much on the organizational and technological levels of the societies under study. For example, if the emphasis is on hunters and gatherers regional definitions may be derived from models of animal population ecology and/or theoretical models of mating networks (Wobst 1974) or the like. At the other end of the continuum, modern economic geographic theory defines regions on the basis of degree of interaction among settlements, functional specialization and transport routes. In other words, the concept of a "region" is conditioned by the kind of phenomenon under study. Hunter-gatherers occupy regions that are several thousand kilometers in extent, early agricultural villages occupy regions that are substantially smaller and a region in the modern sense is one segment of a large urban city.

Most archeologists working in the Southwest adopt an ethnographically-based view that small scale agricultural settlements are economically independent and have difficulty defining regions in a sociological sense. This problem is manifest most obviously in the tendency to develop separate phase chronologies for every individual drainage and has lead to the remarkable lapse of some hundred years before we were able to define the Chacoan phenomenon as an integrated system. Unfortunately, southwestern archeologists have not investigated contemporary villages, because we have assumed, correctly, that these are imbedded in modern national states. In failing to fully use the available ethnographic literature we have neglected an important series of useful case studies. For example, regional interactions between wet rice culti-

vators in interior Burma and hillslope slash and burn dry rice agriculturalists (Leach 1965) provide a situation that is suggestive of the kinds of interactions that may have obtained between resilient and more stable systems in the Southwest. Similarly, and closer to home, we have largely neglected interactive patterning between Athapaskan and Pueblo populations.

## Settlement Configurations

We suggest, using some of the information we have already presented, that a village and all of the logistical sites associated with it forms the core of a potential region. Further definition of a region might include "empty space" used as a resource area. The region would then also be delinated by the network of exchange materials among communities of comparable size and their logistical sites and sustaining areas. It should be pointed out that in attempting to define certain classes of sites in the Southwest that the concept of "site" may require redefinition. For example, there are many instances where large settlements are surrounded by a continuous scatter of materials and are associated with many extramural features that may extend several kilometers from the parent village. In other cases, such as the Hohokam area, there is a good deal of information that sites grew by acretion over several centuries. In all of these instances some attempt must be made to relate the appropriate physical manifestations with a definition that is consistent with the idea of "functioning community."

Models derived from economic geography have been adopted recently by southwestern archeologists who would presumably try to overcome the more traditional biases of treating each individual "site" as an independent economic entity. The uncritical use of central place theory, rank-size models, fall-off curves and the like have resulted in a situation in which the expectations of these models are assumed as fact. While some insight can be gained by employing these models using prehistoric data, most often the conclusions that are generated are unwarranted. What is required at this point is to investigate the assumptions of the models that have been borrowed and question their applicability to the situation at hand. In cases where the isomorphic relationships between situations that obtain in the modern world are found in data derived from prehistoric contexts, it is appropriate to turn to ethnographic contexts on a world wide basis to determine if other economic patterns exhibit similar isomorphisms.

The location of settlements is a response to a variety of environmental, economic, and social conditions. In part, a settlement must make use of those resource that are available in the immediate environment. Resources can also be obtained logistically or through exchange. Given these options, far greater understanding of small scale agricultural societies is required prior to assuming that settlement positioning is conditioned primarily by proximity to particular resources. An example of this can be found in the case of Nuvaqueotaka which is located a short distance from the Government Mountain obsidian source in Arizona. While much of the obsidian at this site has been sourced to the Government Mountain locality, a portion of the obsidian is also from the Jemez Mountains of New Mexico.

## Settlement Implications for the Adoption of Agriculture

In the previous paragraph we have indicated the danger in assuming that agricultural

communities are located in proximity to certain critical resources. Similarly, we would caution against acceptance of the notion that all agricultural communities were occupied on a yearround basis. Nevertheless, we suggested that maintaining sufficient stores for overwintering or to weather the leaneast periods of the year may have been important factors in the adoption of agriculture. Certainly storage facilities and relative permanence of villages was prominent in the Southwest once agriculture was adopted. In general, the archeological remains of agriculturalists are relatively obtrusive in the archeological record. Given that wild resource procurement, especially hunting, continued to be important during the prehistoric period the remains of these relatively less obtrusive activities must be actively sought. The archeological record of an agricultural group would, of necessity, consist of both sites and locations (Binford 1982). Over time it is clear that any given site may become a location (e.g., the last occupation of the Joint Site) and vic. versa. It is important for us to determine the consistency with which such transformaions do or do not take place.

The distribution of settlements on the landscape is conditioned by underlying demogrphic factors. We suspect that in situations of low regional packing the relationships between human groups and natural resources are most critical. When regions become relatively packed, the relationships between human groups and other human groups are more important to structuring the distribution of sites on the landscape.

Given the fluctuations in resources and the changes in the distributions of human groups over time in the Southwest, it becomes an important empirical issue to determine which factors are most critical to settlement placement at any point in time. When approaching this empirical question archeologists should realize that when investigating human group/environmental resource relationships we must examine the spatial relationships between sites, localities and natural resources. On the other hand, when investigating the relationships between settlements and settlements, the focus of investigation becomes the distribution of artifact types and assemblages and the relationship of sites to each other.

While it is impossible at this point to specify exact parameters, we believe that there are certain threshhold values that can be determined which are relevant to defining those interaction processes that initiate change. In some cases, the changes we have described may be related to density dependent factors. In such cases, we believe that it is possible to determine what density values, under particular environmental conditions, are crucial. Similarly, the organizational changes that accompany agricultural intensification are related to threshhold values that pertain to the distribution and packing of groups on the landscape. Finally, patterns of economic interaction likely are correlated with both packing and organizational changes. Again, we believe there are threshhold values that can be specified under particular environmental constraints. We suggest that the formulation of general models regarding threshhold values is an appropriate endeavor. In the absence of well developed theory in this area, a combination of comparative ethnographic studies, mathematical modeling and experimental archeological investigations will prove useful.

As a final consideration with respect to settlement, we will address the issue of the expanding catchment areas of agricultural groups. It is a fact that certain ethnographically known groups in the Southwest, maintain relatively enormous sustaining areas that are used for a variety of purposes. We will provide four examples here, briefly indicating the principles underlying the size of the areas involved.

In the case of contemporary Laguna Pueblo, farming activities are carried out an average of 13 miles from the residential villages. At Laguna, hunting parties range an average of 80 miles from the villages, and collecting and gathering activities take place an average of 47.75 miles away from the villages (Cordell 1979). Compared to many other Pueblos, especially those of the Rio Grande Valley, the setting of the Laguna Villages is relatively impoverished in respect to natural resources, and this is reflected in the large catchment area.

Another example is provided by the Hopi who range in two principle directions to obtain materials for ritual and ceremonial use. These areas, the San Francisco Peaks which are some 80 miles distant from the mesa, and the scarps and ledges of Anderson Mesa, approximately 100 miles away, are used to collect eagle feathers, spruce boughs, and specific minerals and pigments. Although today these areas are used largely for ritual purposes, they are components of the ancestral range of the Hopi.

Recent land claims data from Zuni Pueblo (Ferguson 1980) document Zuni use of an area extending from the Grand Canyon to the Sandia Mountains. As is the case with the Hopi, the Zuni sustaining area is primarily involved in obtaining ritual paraphernalia, although more direct economic uses are cited for the prehistoric period. Importantly, the Zuni sustaining area is in no sense considered to be "owned" or an exclusively used territory. Rather it is an area of customary use that was probably shared with other pueblo groups.

Our fourth, and last, example is from the prehistoric site of Nuvaqueotaka in central Arizona, located some 35 miles southwest of Winslow. Although inferential, data suggest that during the 14th century, the inhabitants of Nuvaqueotaka, had extended their catchment range by several hundred miles. This information is derived primarily from the non-local commodities found in the deposits of the site. Various source analyses have indicated that turquoise was being obtained from as far away as southwestern New Mexico (Tyrone). Pottery from all over the Plateau Southwest was present in the deposits of the site. In addition, shell both from the Gulf of California and from the Pacific Coast, are present in substantial quantities. Copper bells, presumably from Casas Grandes have also been recovered. Although these commodities are not edible resources, there are data to suggest that Nuvaqueotaka was a central node in a pan-regional exchange system. As such, it is possible that the substantial quantities of non-local goods were being used in a banking strategy that buffered subsistence stress. In other words, contact with widespread regions that effectively extended the catchment zone of the community was a mechanism for ensuring the survival of the group (Upham 1982).

These examples indicate both the complexity of defining "agricultural sites" and their sustaining regions, and the importance of considering catchment areas when dealing with agricultural communities. We suggest that until southwestern archeologists regularly look beyond the site and the local drainage and/or survey area, a great

deal of critical information will be overlooked. Particularly in the exercise of developing predictive models, it is essential that a broadly regional approach be adopted.

## THEORY DEVELOPMENT FOR AGRICULTURAL GROUPS IN THE SOUTHWEST

Throughout this section, we have indicated specific areas in which theory is poorly developed or nonexistent. We also specifically noted that there is little in the way of theory relevant to southwestern agriculturalists that is available in disciplines that are subsidiary to or outside of anthropology. In many cases, we have indicated that archeological thought has relied on untested assumptions about the behavior of agriculturalists, and in each of these, further theoretical development is requisite.

Rather than reviewing each of the specific issues requiring theory here, we would like to mention two, additional and very general notions about which we are concerned. First, as archeological scientists we work within a framework of "etic" categories appropriate to our discipline. Thus, we may describe certain climatic factors in terms of effective temperature or define soils in terms of their mineral content or moisture retaining properties. While this in itself is not problematical, we note that most general scientific usage is based upon Western European patterns of landuse. These, of course, relate to a tradition of mixed animal and plant agriculture that is not necessarily appropriate to southwestern agriculturalists. It is possible that certain environmental characteristics, important to southwestern agricultural groups are not easily extracted from our own scientific frames of reference. Second, on a more positive note, we hope that our discussion departs from more traditional approaches in focusing on potentially measureable processes. The archeological record of horticultural societies is at once more obtrusive and durable than that of hunter-gatherers. This may permit us some insight into relative investments of labor, which is more meaningful in terms of behavior than ethnographically derived, "emic" categories.

As a final note, we would hardly characterize the present exercise as an example of theory building. We hope that we have suggested the areas that need such an effort, and provided some direction for the paths theory building might take.

# TRIAL MODEL BUILDING

## INTRODUCTION AND BACKGROUND

Fred Plog

### INTRODUCTION

The second major focus of the conference was an empirical effort to design surveys based upon actual relationships between site distributions and environmental patterns. Conference organizers sought to identify survey data broadly representative of different areas of the southwest. Further, surveys of at least 1000 acres were sought. It was the conclusion of the organizers that surveys of any lesser land mass would be unlikely to contain variability sufficient for investigating environmental relationships. In many respects, it would have been desireable to have even larger survey areas than those ultimately selected. However, the set of areas for which analyses were undertaken provide a data base that is paralleled only by SARG in terms of the area of coverage and the number of sites involved.

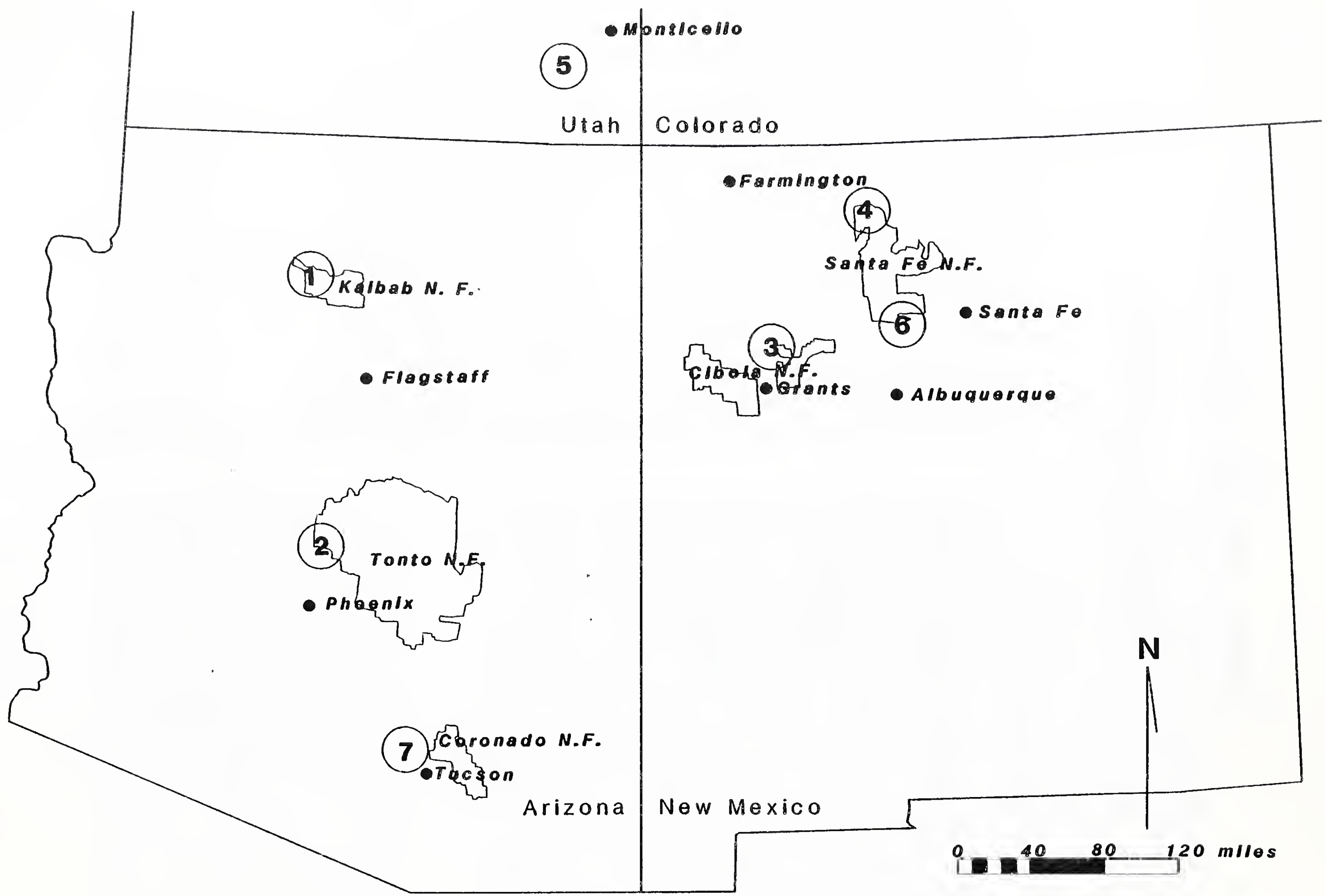
### STUDY AREAS

A number of specific areas were studied, Map 1. On the Santa Fe National Forests, a survey unit in the traditional "Gallina" country north of Cuba, NM, and one southeast of Jemez Springs were investigated. Both of these areas were initially surveyed as a part of timber sales. The survey unit utilized on the Kaibab National Forest was also the result of a timber sale conducted in that area. Survey units on the Coronado, Kaibab, Tonto and Manti-LaSal National Forests were generated in a somewhat different fashion. The Tonto Unit is a result of the NSF sponsored CAEP survey directed by George Gumerman. The Coronado Unit is the result of the recent research interests of Paul Fish, which has led to a substantial investment of graduate and undergraduate survey efforts in the execution of this effort. Data from the Kaibab National Forest were generated through both surveys done in conjunction with timber sales and sample survey undertaken for planning purposes. The Manti-LaSal data were gathered as part of the Cultural Resource data base for Land Management Planning on the Monticello Ranger District. These are the data bases with which the analytical effort began.

Initially six study areas were selected with one backup, Map 1. The backup data base (Study 3) was not used. Numbers of the study areas were assigned on the basis of when they became available. Study Areas 1, 3, 4, and 6 were brought up from existing Forest Service files. Studies 2 and 5 were borrowed from the SARG data base and entered in Forest Service format through a conversion routine written by Landon Smith. Study 7 was entered into the data base through a punch card file provided by Paul Fish.

### DESIGNING LIMITED SURVEYS

While the conference is described as a predictive modeling conference, the actual analyses undertaken can be described somewhat more succinctly. Participants sought to identify survey strategies which, had




Map 1. Study Areas

they been employed, would have located all or most of the sites in each project area using less than inventory level survey. While this activity implicitly involves predicting the location of sites, we found the use of the term predictive model to be problematical for a number of reasons.

First, as currently used this term refers to quantitative analyses of site locational data, often multivariate analyses. While we do not question the utility of such undertakings, they do not include the full range of "predictive" activities that archeologists utilize. In essence, archeologists have been involved in the use of predictive models, albeit highly intuitive ones, throughout the existence of the discipline. Whenever an individual made a decision that a particular area was a worthwhile location for survey archeology, an intuitively based predictive model was utilized.

Subsequently, land managers began to approach the survey issue, in the case of timber sales, using sampling strategies. Areas in which sites were not found were excluded from further study, often on the basis of implicit rather than explicit predictive models. The generation of more quantitative versions of such models began with the work of the Southwestern Archaeological Research Group (Gumerman 1971, 1972; Euler and Gumerman 1978) and their attempts to determine why sites are located where they are. Over the last five years, explicitly quantitative models have been generated for a number of projects. Some of these are complex multivariate analyses resulting in predictions that are difficult to translate into English. We do not regard the development of such models as a necessary improvement over ones that are based on clear logic or ones based on simpler statistical procedures.

A second problem is the enormous political debate that has occurred within archeology during the last year that focuses on predictive models. While this debate has presumably been resolved by the resolution passed at the recent meeting of the Society for American Archaeology that supports the wise development and use of such models, it has greatly confused the issue of precisely what archeologists have in mind when the term predictive model is utilized. Despite the millions of acres that have now been surveyed in the U.S. as a part of sample strategies and the millions of acres that have been cleared on the basis of these samples, much of the discipline currently understands the concept of predictive modeling to refer to something very new. For these reasons we wish to emphasize our own focus on the design of survey research.

## STUDY QUESTIONS

The specific questions that each of the participants in this component of the conference sought to answer were the following: (1) How much of the survey area under study could have been omitted from survey either because it contained no sites or because site density in the area was exceptionally low? In essence, each participant sought to bound a low density zone. These were not narrow zones weaving in and out among sites, but contiguous blocks of land. (2) How different are the sites that would have been missed because this zone was not surveyed from those that were found in the survey area? This analysis was intended to insure that any sites missed were not unique, did not appear to represent key information that would have rendered subsequent interpretation problematical. (3) What environmental information is available for the project area? Because different forests are in different stages of planning and of mapping different environmental

characteristics, the available environmental data varied from area to area. Each participant examined whatever data were available. (4) Can one define the zones of high and low site density on the basis of some environmental characteristic? In essence, this component is the predictive one. If such zones can be identified then environmental information can be used in planning future surveys so that the focus is on the high density zones. Sampling, reconnaissance or some other strategy could be used to verify the effectiveness of the model in the new area. (5) Is there additional information in the available data that might prove helpful in designing surveys? (6) What were your thoughts about the utility of the analyses you have done, the implications for survey research, and the need for additional study that might refine the survey strategy identified?

In answering these questions, each participant had the following data: (1) a map of site locations in the study area, (2) USFS site records for each of the sites, (3) a computer summary of pertinent environmental and cultural characteristics of sites in the area, and (4) one or more environmental maps. The results of the investigations will now be summarized project by project.

# STUDY AREA 1: KAIBAB NATIONAL FOREST

Fred Plog

## DESCRIPTION

This study area consists of almost 12,000 acres on the Tusayan Ranger District located immediately south of the Grand Canyon on the Kaibab National Forest. These data were generated through survey of three separate timber sale areas, Tusayan, Mistletoe, and Hammer (Cartledge 1977, 1980; Simpson 1978; Wood 1976). The area of the sales is an upland plateau dissected by intermittent streams. Elevation is between 6400 and 7300 feet. Major vegetative communities are pinyon-juniper, ponderosa, and sage. Some areas are covered by complex blends of these types.

Prehistoric occupation of the area began during the Desert Culture period. Later evidence is of Kayenta Anasazi, Virgin Anasazi, and Cohonina peoples. Small lithic scatters occur in high densities over the entire area. Other types of sites found in lesser numbers include masonry structures, artifact scatters, rock shelters, and rock art sites.

## PREVIOUS STUDIES

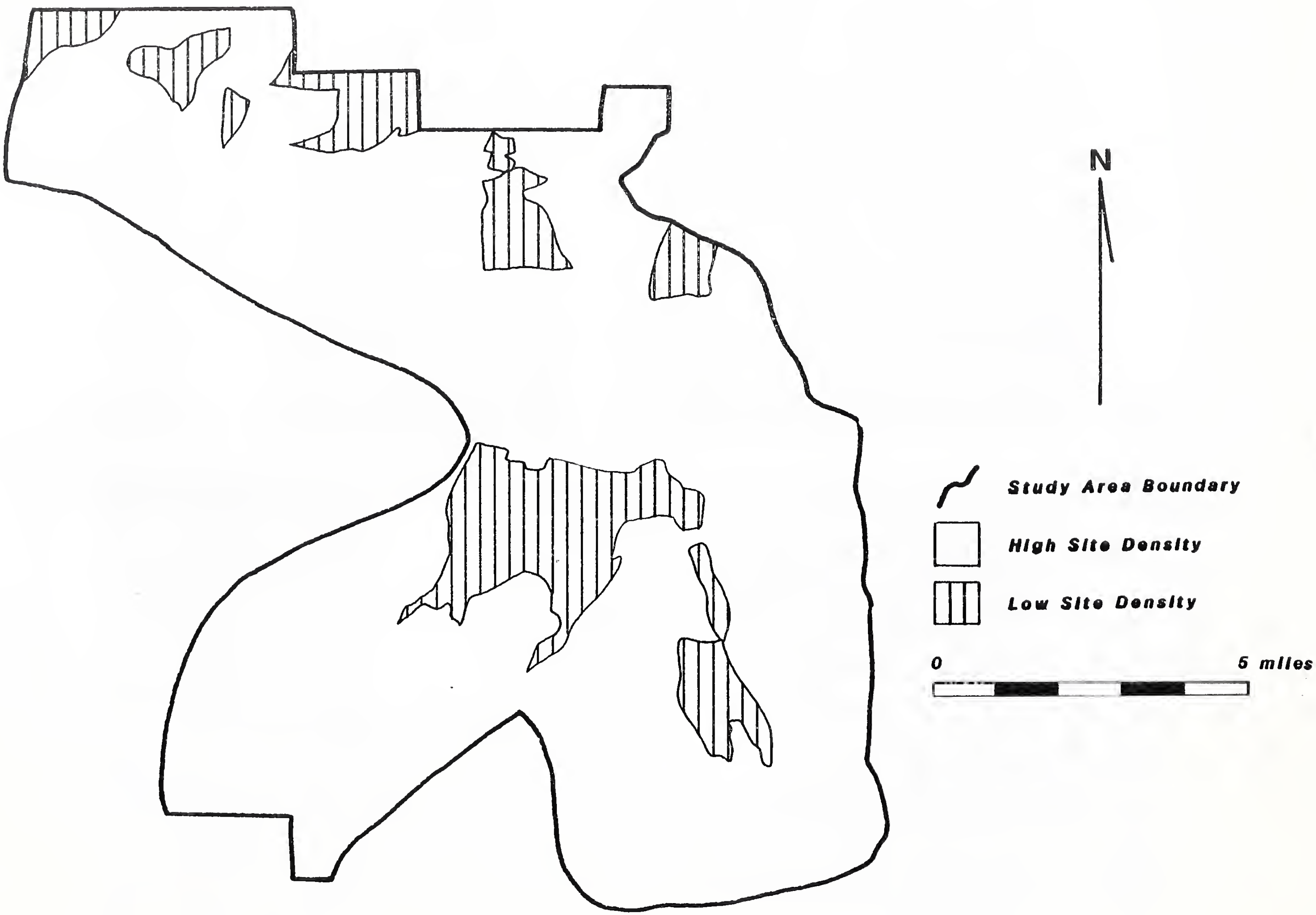
In addition to the timber sales, two planning studies were conducted in the area (Effland and Green 1979; Rice, Effland, and Blank-Roper 1980). Both studies were 1% samples of the area using transects. Because these additional data were available, this study area was investigated differently. Our effort focused on the predictions that would have been made for the area based upon the planning studies. We attempted to determine how accurate these predictions would have been.

Two management decisions effected our ability to complete this task. First, because lithic scatters are ubiquitous in the area and because it is unclear that timber harvests have a substantial negative impact on such sites, recording of these scatters has been discontinued. Thus, more such sites occur in the areas of the timber sales than the data include. Second, survey is complete only in the case of the Mistletoe Sale. In the case of the Tusayan sale, survey has been restricted to areas of direct impact. In the case of the Hammer sale, "no cut" areas were not surveyed. These are areas where pinyon-juniper are dominant and are known to contain a large number of masonry sites. Thus, the numbers of small lithic scatters and masonry structures are underestimated in the sale data.

The predictive model generated in the study pertinent to the sales, Effland and Green (1979), is based upon a combination of two environmental variables. The planning unit was first separated into different drainages at the ridge lines bounding those drainages. Then, each drainage was divided into further zones on the basis of vegetation. Three strata were utilized ponderosa, mixed ponderosa and pinyon-juniper. Site densities were calculated for each of these zones.

## ANALYSIS

Site densities proved to be highly variable in the sale areas. These figures are shown in Table 2. Map 2 shows the high and low site density zones for the study area.




Map 2. Study Area 1, Kaibab National Forest

Table 2. Sites per acre, Study Area 1.

| SALE | Sites | Acres | Acres/Site |
|---|---|---|---|
| Hammer | 123 | 6766 | 1/55 |
| Mistletoe | 1 | 2076 | 1/2076 |
| Tusayan | 63 | 2325 | 1/40 |

The one site found in the Mistletoe survey was a lithic scatter, the type that is no longer being recorded. Thus, this area was surveyed at considerable expense given that it yielded so very little information. One can ask whether the predictive model generated in the planning document would have allowed a no survey decision to be made concerning this sale.

In Table 3, site densities are broken down by the pertinent drainage and vegetation zones used in the model. Observed site densities are compared to those predicted in the model and to an overall evaluation of sensitivity that occurs in the plan.

Table 3. Site densities by drainage and vegetation zone, Study Area 1.

| STRATA | OVERALL DENSITY | MASONRY AND ARTIFACT SCATTERS | SITE DENSITY PER MI 2 | SITE DENSITY | | |
|---|---|---|---|---|---|---|
| | | | | MASONRY | ARTIFACT SCATTER | LITHIC |
| C | 32.3 | 8.1 | 6 | High | Medium | Low |
| D | 9.2 | 1.4 | 4 | Low | Low | High |
| L | 22.6 | 7.5 | 4 | Low | High | High |
| M | 10.0 | 4.9 | 0 | Low | Low | Low |
| O | 5.8 | 1.8 | 2 | Low | Low | High |
| P | 3.1 | 2.0 | 0 | Low | Low | Low |

It is obvious that a variety of incorrect decisions would have been made had this model been utilized in planning the timber sale. Area M, with the third highest site density, was predicted to have low densities of all types of site. Had it been eliminated along with D, O, and P on the grounds of overall low site densities or high densities of lithic sites only, major problems would have arisen during the subsequent sale with a substantial adverse effect on cultural resources.

This problem seems to have arisen because the predictive model was generated in a non-quantitative fashion. For example, no rational is given for dividing the area into drainages. Area M was assigned a value of 0 apparently because no transects were surveyed in it. In this case and several others, one crosses a line and moves from a very high density to a very low density area. Such an eventuality is somewhere between unlikely and impossible. Visual inspection of the distribution of

sites in the transect survey suggests that, had SYMAP or some other spatial smoothing program been employed, a successful predictive model might have been generated. There is little question for example, that such an analysis would predict that M would be a high or at least moderately high density area and that the area of the Mistletoe sale is probably the lowest density area on the district. A subsequent analysis evaluating the sale results on the basis of such a technique is recommended.

## STUDY AREA 2: TONTO NATIONAL FOREST

John C. Ravesloot and Peter J. Pilles

### DESCRIPTION

Study Area 2 consists of a contiguous block of 2728 acres that was surveyed between 1971 and 1976 as part of the Central Arizona Ecotone Project (Gumerman and Johnson 1971; Gumerman et. al. 1976; Spoerl and Gumerman in press). It is located about 30 miles north of Phoenix, Arizona between the Bradshaw and New River Mountains. The town of New River is 6 miles west of the study area.

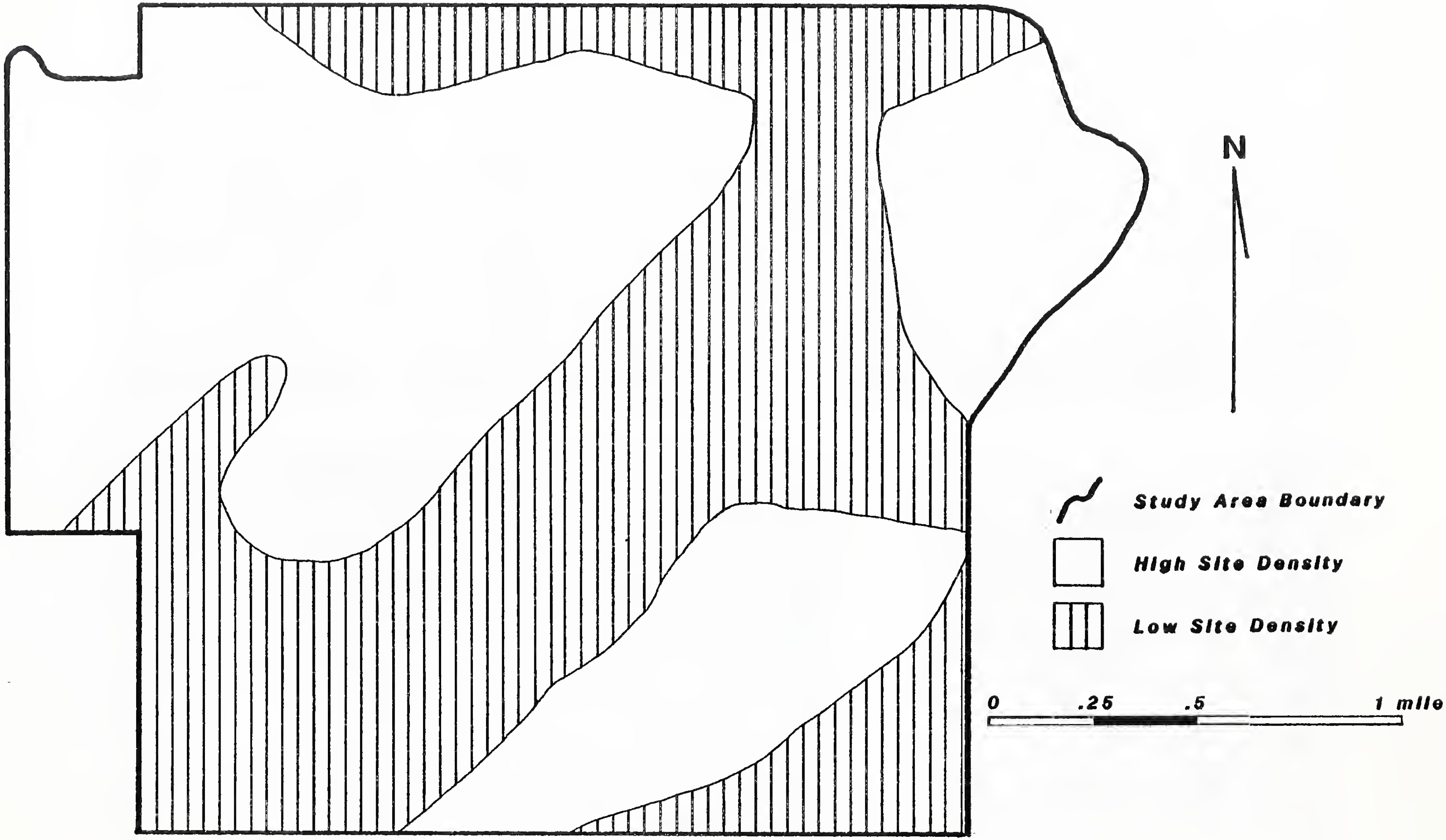
The north and eastern portions of the study area are bounded by the escarpment of New River Mesa while the southern and western portion is formed by gentle, colluvial ridges that slope downwards to the southwest. Major topographic relief is also provided by two prominent hills that rise almost 1000 feet above the desert floor. The country is gently sloping and highly dissected by numerous washes that form the Cline Creek drainage system. This system is a major tributary of New River, which is located about 5.5 miles to the west. The washes of the Cline Creek system drain the flanks of New River Mesa and only flow after summer and winter rain storms. Permanent water sources presently known in the area are Shoemaker and Quail Springs. There is little elevational variability since there is only a change of 1000 feet from the highest to the lowest parts of the study area.

In general, the major vegetation of the study area is part of the saguaropalo verde-bursage community of the Lower Sonoran Desert. The dominant vegetation of this zone consists of saguaro (Carnegia gigantea), palo verde (Cercidium sp.), ironwood (Olneya tesota), ocotillo (Fouquieria splendens), bursage (Franseria deltoidea), prickly pear (Opuntia sp.), jojoba (Simmondsia chinensis), and numerous varieties of cholla such as teddy bear cholla (Opuntia bigelovii), buckhorn cholla (Opuntia acanthocarpa), and chain fruit (Opuntia sp.). The lower areas are characterized by creosote, bursage, and several varieties of cactus, while the higher, rocky slopes are dominated by palo verde, jojoba, prickly pear, and ocotillo.

### AREA PREHISTORY

The earliest evidence of human habitation of the New River region consists of Cochise sites that have been recorded along New River itself. However, in the study area, occupation appears to begin about A.D. 800 and continues until about A.D. 1150. This time span is based upon four radiocarbon dates and four obsidian hydration dates recovered from two excavated sites as well as the decorated ceramics found at the surveyed sites (Ravesloot and Spoerl in press; Spoerl 1979; Spoerl, Ravesloot, and Gumerman in press).

It is believed that the archeological remains of the New River area are attributable to communities representing the Hohokam cultural tradition. This occupation is considered to have initially represented the seasonal exploitation of the upland desert resource zone during the late Co-lonial Period and which by Sedentary Period times consisted of a resident population which supported itself by maize agriculture, hunting, and a major reliance




Map 3. Study Area 2, Tonto National Forest

on gathering desert resources (Bohrer in press; Spoerl 1979). This major use of the desert upland resource zone between A.D. 1050 to 1150 may correspond with a period of more effective moisture for the Southwest as suggested by recent environmental studies of the Plateau (Euler et. al. 1979).

## DATA BASE

A total of 89 sites representing eight site classes have been recorded within the 2728 acres of the study area. Two of these sites were inadequately documented and were deleted from the sample used for this study. Figure 2 presents the frequency distribution for the various site classes. Map 3 shows the high and low site density zones for the study area.

Water control systems (e.g. linear borders, rock-cleared areas, terraces, and gridded borders) were the most common site types recorded. A third of the water control systems were associated with one-to-two room field houses. The walls of the field houses were constructed of either slabs with rubble core or piling of unshaped rocks. Surface villages were defined as consisting of four or more non-contiguous rooms constructed of upright slabs and rubble core walls. Pithouse sites were indicated by a rather dense and diverse concentration of artifactual remains that extended over a large area. Refuse scatters were identical to pithouse sites but were generally smaller in size and had lesser artifact variability although it is possible that some of these may actually be pithouse sites. Hilltop sites, although few in number, appear to have represented the major focus of the settlement system of the New River area. The paucity of datable surficial remains precludes percise temporal placement of the sites. It is suspected that pithouse villages were occupied prior to hilltop sites, although this cannot be demonstrated with certainty.

## ANALYSIS

In analyzing the distribution of sites within the study area it was determined that 82 (94%) of all sites occurred in 60% (1622 acres) of the area examined (Figure 3). Site density within this zone consisted of 32 sites per square mile. Of the five sites not included within this area, two were field houses, one was a field house with a water control system, one was a rock-cleared area, and the remaining one was a hilltop site. The above site types, with the exception of the hilltop site, were adequately represented within the identified zone of major site density. This particular site is considered unique because it is a single room encircled by a wall while the other hilltop site consisted of 70 rooms on various levels of the hill. By including the hilltop with the previously identified zone of major site density, fully 95% of all sites would have been recorded.

In attempting to understand the distribution of sites within the study area, a number of environmental and cultural variables were examined. Soil and vegetation have proven to be important indicators of prehistoric site locations in many areas. However, the vegetation is fairly uniform throughout the area while available soil information is too general to be of use at the present time. Environmental information available for analytical purposes consisted of general topography, onsite slope, elevation, and drainage ranking.

Figure 4 presents the frequencies of sites by 60 feet increment of elevation. Fifty-nine percent of the sites are situated be-

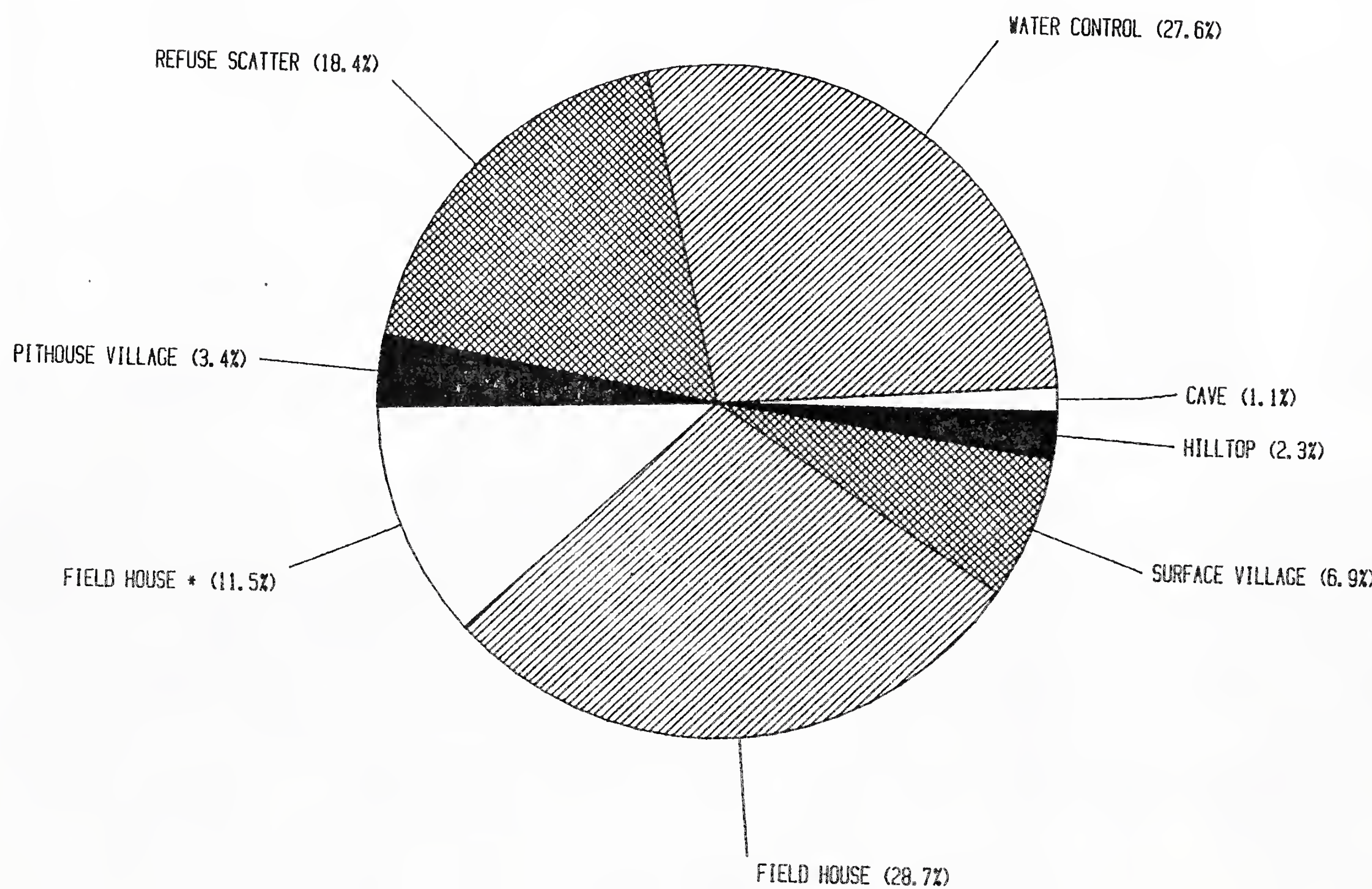



Figure 2. Site Type Frequency Distribution, Study Area 2

tween 2320 and 2550 feet. The remainder are fairly evenly distributed throughout the other elevational groupings with the exception of the two hilltop sites. The results of a random distributional study of elevational points (Figure 5) indicates that this pattern is non-random.

General topography was found to be the most important determinant of site location. For example, an examination of on-site slope indicated that 54% (N=47) of the sites occurred on generally flat land with slopes of less than five percent. This was particularly evident with regard to the distribution of water control systems, pit house villages, and refuse scatters. The central portion of the study area is comprised primarily of colluvial slopes originating from the base of New River Mesa. Water control systems and field houses were primarily found along these colluvial slopes with the exception of the southwestern portion of the study area. The lack of sites in this area may be due to any one of several factors: 1) Sites may be present but are not observable since they may have been covered by colluvial deposition. 2) Runoff conditions are not optimal for dry farming on these lower slopes. 3) The survey may have missed sites in this area. 4) Settlement distribution indicates the flanks of New River Mesa and the base of the buttes on which the hilltop sites were located were the favored loci for occupation.

The distribution of sites relative to the size and rank of drainage segments within the Cline Creek drainage system was also examined with negative results. Practically all sites are located in proximity to a segment of this drainage system. In addition, it is likely that water did not flow perennially in these drainages in prehistoric times, and therefore, the distribution of sites along these washes is relatively meaningless for predictive purposes.

## RESULTS

In sum, on the basis of environmental information available for this study, topography was found to be the most important variable for site locations. Specifically, the dominant hills were selected for construction of the large, defensible villages that most likely formed the focus of the settlement system assuming that all the sites were occupied contemporaneously. The colluvial slopes around these hills were also selected for construction of the numerous water control systems and their associated field houses and small villages.

The results of this study provided information that is of limited utility for designing survey sample strategies to recover the majority of archaeological sites in an area with minimal survey coverage. A survey strategy based solely on the topograhic relationships identified here would still require the study area to be complete inventoried, rather than sampled. More precise locational relationships need to be identified before sample strategies can be designed that would result in lower inventory costs. For example, it is strongly suspected that if detailed soil information was available, a correlation between several site types, especially water control systems, and certain soil types could be demonstrated.

The present study also realizes the difficulty of defining the precise environmental and cultural variables which determine site locations within a particular region on the basis of a small sub-regional sample. This is particularly a problem in a region such as New River which is topographically

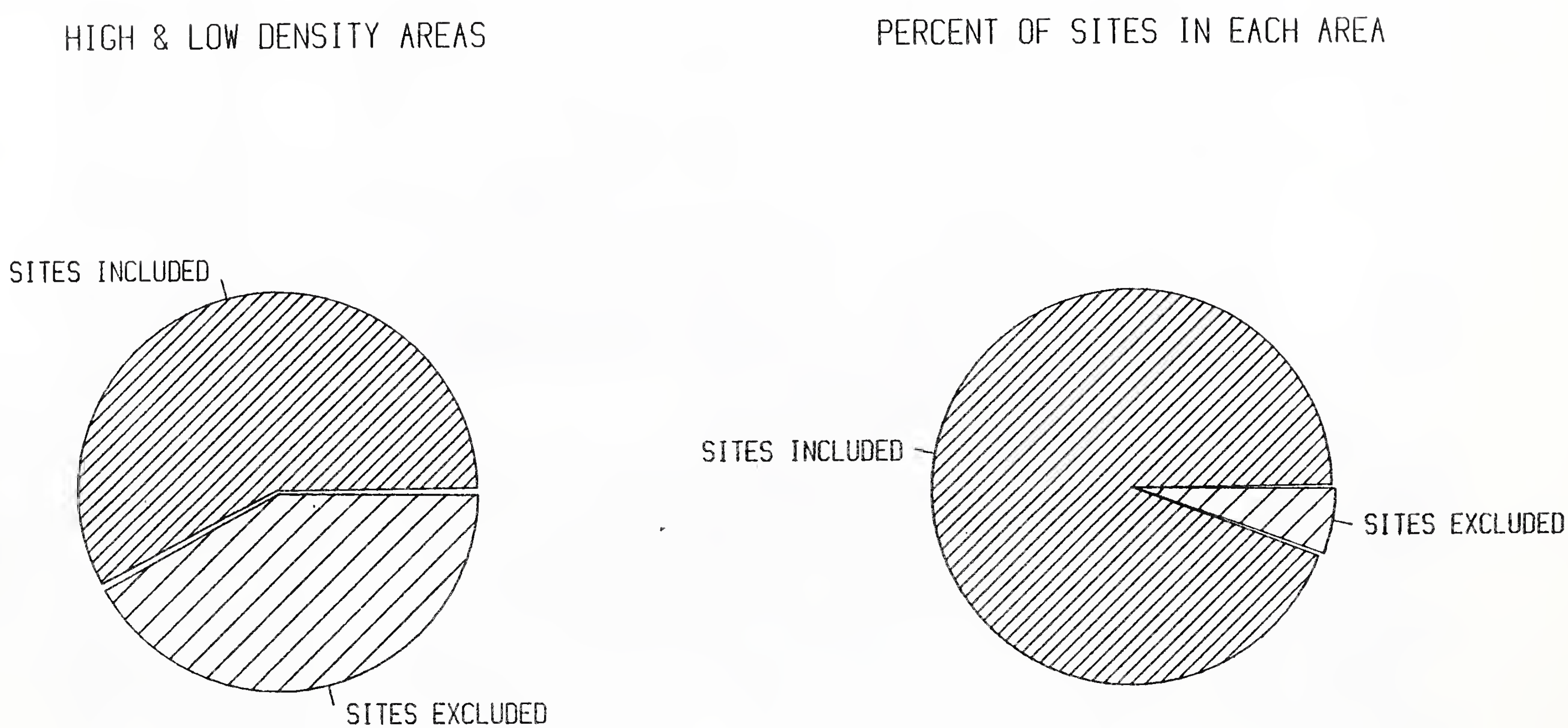



Figure 3. Site Densities, Study Area 2

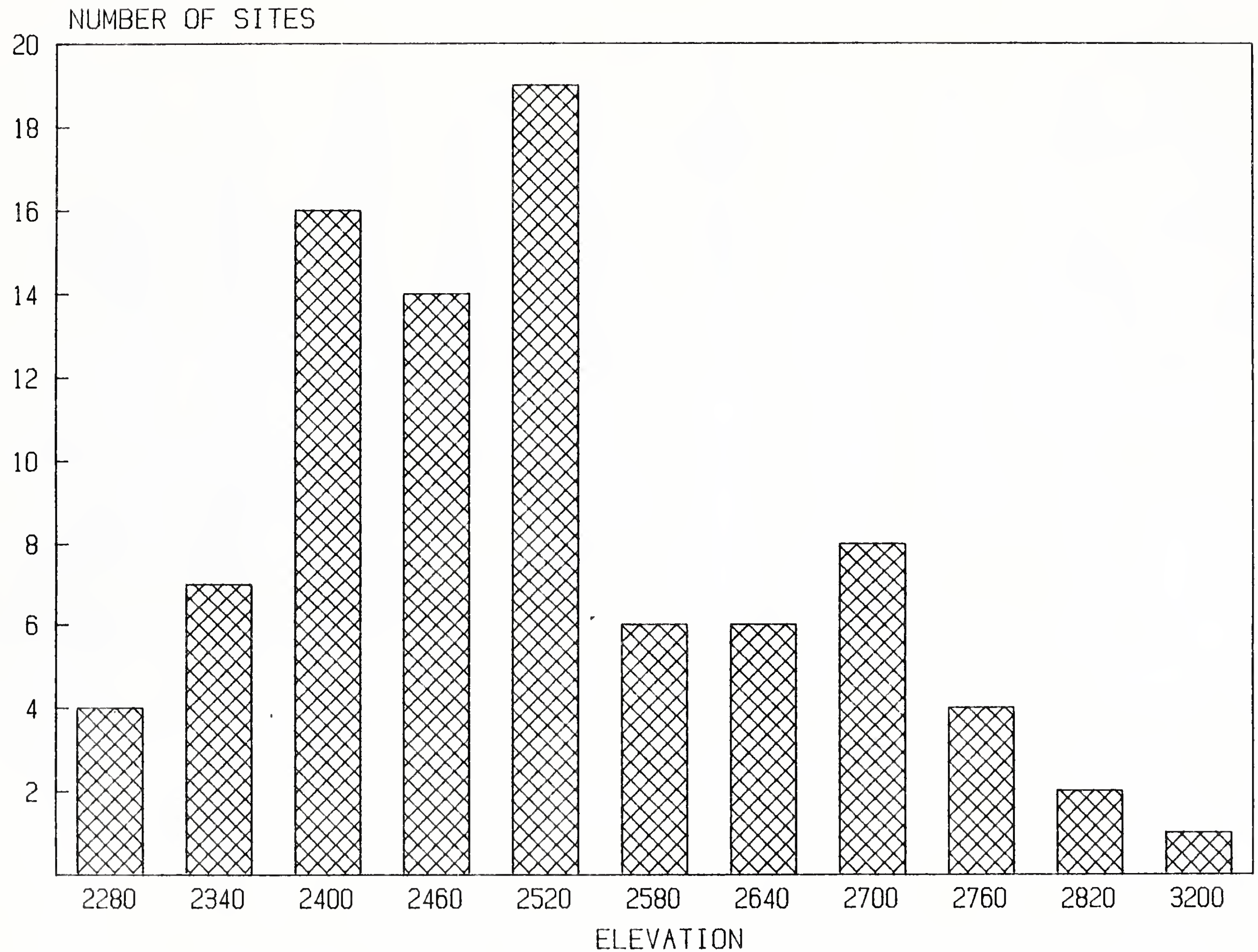



Figure 4. Site Frequency by Elevation, Study Area 2

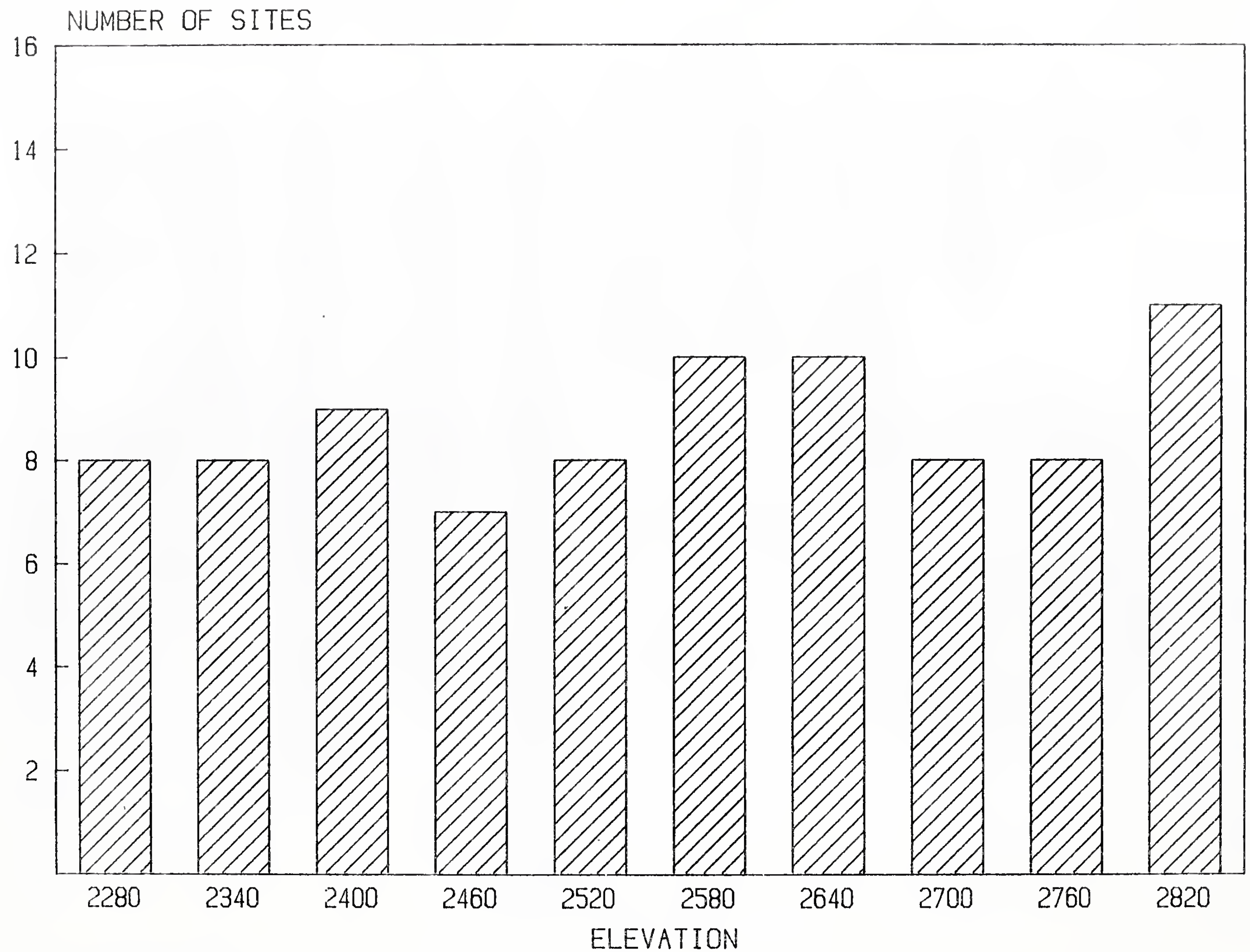



Figure 5. Random Elevations, Study Area 2

diverse. For example, the combination of topographic relief and site densities contained within an area the size of the study area may well be unique. In order to precisely define those relationships between environment, topography, and cultural factors that truly represent the entire New River region, a larger or differently bounded study unit may be necessary. It does appear, however, that topographic relief may have been a major variable which determined site locations within this region. An area to the north of the present study area was also completely surveyed by the Central Arizona Ecotone Project. In this area, high hilltops and gentle slopes were also found to be areas of major site concentration, although site density was not as great.

## STUDY AREA 4: CUBA DISTRICT, SANTA FE NATIONAL FOREST

Fred Plog

### DESCRIPTION

Study area 4 is on the Cuba District of the Santa Fe National Forest. The data utilized were generated during survey of the Boot Jack Timber Sale (Dick 1981; Lawrence 1982). The sale area is bounded on the north by the Jicarilla Indian Reservation and on the west by the continental divide.

This upland zone is heavily dissected by intermittent streams. Thin, steepsided ridge lines separate narrow valley. Valley floors are typically covered by sage. Slopes and ridges are covered with pinyon, juniper, ponderosa, Douglas fir, mountain mahogany and scrub oak. Elevation varies between 7800 and 8450 feet.

### AREA PREHISTORY

Prehistoric occupation of the area appears to have been limited to a very short time period between about 1150 and 1250 A.D. During this epoch, a distinctive southwestern culture, Gallina, existed in the area. These people were responsible for types of sites including jacal structures, mud and boulder structures, pithouses, towers, reservoirs, and check dams.

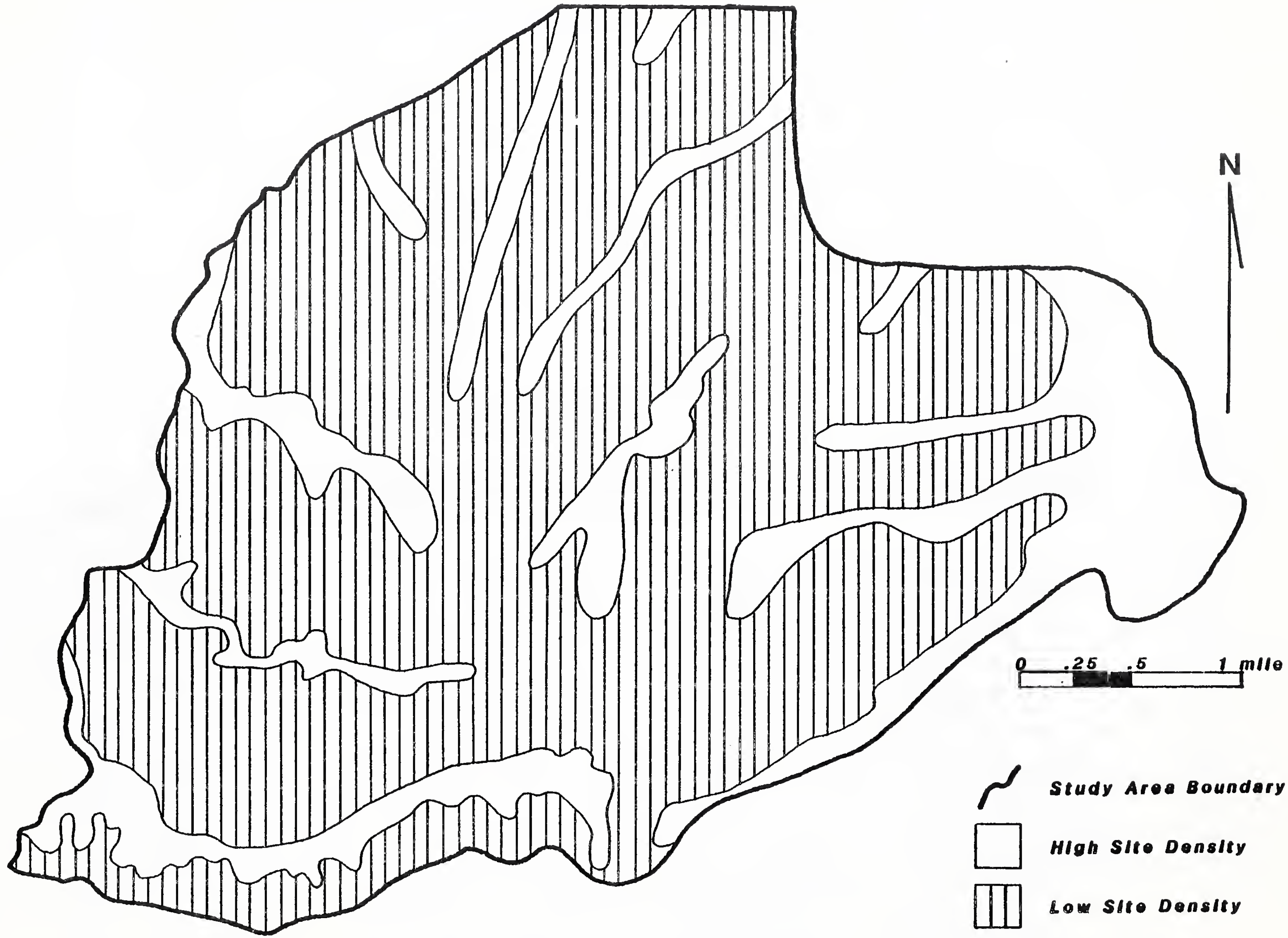
### DATA BASE

The portion of the sale area used in the study includes a total of 8464 acres. During survey of the area, 142 sites were located. The vast majority of these sites occur along the ridge lines. Map 4 shows the high and low site density zones for the study area. Had survey been limited to these ridge lines, 96% of the sites would have been located. Only 23% of the area would have been surveyed in order to locate these sites. Perhaps because the area was utilized by a single group of people for a relatively brief time period, the pattern of site distribution is exceptionally regular. Settlement patterns comparable to those in the area are far more characteristic of settlement systems along major rivers.

Three of the five sites that fall in areas off of the ridge lines may, however, provide important and unique evidence concerning the area. One of the two field houses located during survey of the sale, and two of the seven limited activity sites located occur on the valley floor. The survey in question was conducted in part by USFS crews and in part by a contractor. All of the valley floor sites were found by the USFS crew. Thus, there may also be more of these unique sites types elsewhere in the sale area. If one extended survey coverage to include all areas where there is valley floor (many drainages are V shaped and lack a floor) survey could still be limited to 38% of the entire sale area. The Forest Service study of terrestrial ecosystems conducted for the area (Gass, Lucas, and Price 1981) shows variation in the ecosystem on the valley floor in different parts of the sale area. It is possible that further survey would allow definition of those ecosystems in which valley floor sites occur and those in which they do not.

### ANALYSIS

There are two possible reasons why sites are located on the ridge tops. First, the Gallina people may have chosen to conserve agricultural land by locating their living




Map 4. Study Area 4, Cuba Ranger District, Santa Fe National Forest

sites elsewhere. Second, and especially since Gallina pithouses are very deep, it may have been difficult or impossible to maintain stable architectural units in the valleys. Given the steep slopes surrounding the valleys, it is probably that runoff would periodically saturate the soils and flood subterranean houses.

While resolution of this issue is impossible at present, the second explanation seems the more likely. There are roughly 1300 acres of valley bottom in the sale area. It is difficult to imagine a population of more than about 500 individuals. Using estimates for the southwest, these individuals would have required somewhere between 250 and 1000 acres of arable land for farming. Using the figures for dispersion, the aggregated site area in the timber sale is about 32 acres. Thus, it is difficult to imagine that living in the valley would have had a significantly negative effect on the availability of land for agriculture.

## RESULTS

If this interpretation is correct, it would be useful to differentiate between those terrestrial ecosystems in which soils are moist or periodically become waterlogged and those which are generally dry and drain well. The later should have been the preferred locations for dwelling units.

Data from this study area result in as clear a definition of an approach for finding all sites with less than inventory survey as one can imagine. Potential improvements can come through survey of valley bottom locations in the wider valleys that were surveyed by the contractor. Similarly, transects in the narrower valleys to make sure that sites were not missed in these areas would be advisable. Apart from any improvements that result from such efforts, it would be desireable to apply the suggested survey strategy in nearby areas to determine its utility.

# STUDY AREA 5: MANTI-LASAL NATIONAL FOREST

Evan I. DeBloois

## DESCRIPTION

The area under investigation as Study Area 5, is located on the Monticello Ranger District of the Manti-LaSal National Forest, Southeastern Utah. Surveyed in 1971 by a Forest Service crew as part of the Elkridge Archeological Project, the area covered consists of approximately 2000 acres. For the purpose of this examination, the project boundaries were redrawn to exclude irregular areas near the northern edge of the survey. The final area considered consists of 1575 acres containing 162 archeological sites.

The survey area is located just south of Bayles Ranch in the upper reaches of Allen Canyon. The elevation ranges from 6200 feet to 7085 feet near the Bayles Ranch buildings. The area is divided into two major drainage systems, Allen Canyon with a permanent stream on the west and an unnamed intermittent stream on the east of the area. A high ridge with two dominant hills separates the two drainages on a north-south axis for about two-thirds of the distance through the project area.

The area is covered with pinyon-juniper forest with interspersed sagebrush-grassland openings. In the vicinity of Bayles Ranch, a large area has been cleared and planted to pasture. The eastern third of the area contains a relatively broad expanse of colluvial deposits that form a gently sloping valley several hundred yards wide. Bordered by the 7000 foot central ridge on the west and a deeply entrenched creekbed on the east, this valley contains the majority of the archeological sites located.

Allen Creek, the only year-round stream in the area, runs north to south through the western third of the project area. It consists of a relatively narrow canyon with a series of low ridges extending at right angles to the creek. The second most numerous cluster of sites lies along this creek dispersed along these ridges. Another cluster of sites occurs along Allen Creek just above the junction of the two area drainages. Except for the upper reaches of the creek, the majority of the sites are located on the west side of Allen Creek, on east and southeast facing slopes.

## AREA PREHISTORY

Elkridge is a narrow mesa deeply dissected by canyons. The mesa is attached to the western side of the Abajo Mountain mass. Elevations of the mesa range from 7000 to over 8500 feet and most of the upper elevations are covered with Ponderosa Pine forest. The Allen Canyon study area lies at the upper end of one of the series of canyons that have cut into the ridge and which drains the southwestern slope of the Abajo mountains.

Although archeological sites have been known since the earliest settlement of the area, prior to the 1971 survey little scientific work had been accomplished on Elkridge. Reconnaissance surveys by Lipe (1967) and the University of Utah (Marwitt 1966) had examined portions of the Ridge and located minor numbers of sites.

An undisturbed cliff site located by District staff in 1968 led to the employment of two archeologists in the Region by the Forest Service and ultimately to the Elk-

ridge Archeological Project which carried out surveys in 1971, 1972, and 1973. In spite of the considerable amount of area surveyed and the numbers of sites located, little excavation has yet been undertaken to supplement the information obtained through survey.

Test excavations following the vandalism of an alcove site located a mile north of the study area are the only excavations of any kind that have been conducted in the immediate area of the study. Limited work has been undertaken elsewhere on Elkridge, mostly in the form of unpublished test excavations and mitigation projects of limited scale. Work performed on Milk Ranch Point, the eastern extremity of Elkridge, has verified the existence of small and medium sized habitation sites ranging from Basketmaker III to Pueblo III periods. Ceramics from Allen Canyon and Milk Ranch Point show strong similarities and a similar range of occupation and site types appears likely between the two areas.

## DATA BASE

In examining the characteristics of the archeological sites distributed throughout Allen Canyon, a number of attributes stand out as non-randomly distributed. It is upon these attributes that we place the most reliance for discovering the means to refine our survey methods. It is clear from an examination of the study area map that the sites found are not randomly or uniformly distributed across the landscape, but rather are clustered in the two major drainages. It is possible by drawing a line around these major clusters, to separate the area into two site density areas (Map 5). The first area, with .182 sites per acres, consists of 53.4% of the area surveyed. The second area, with .011 sites per acres, includes the remaining 46.6% of the area.

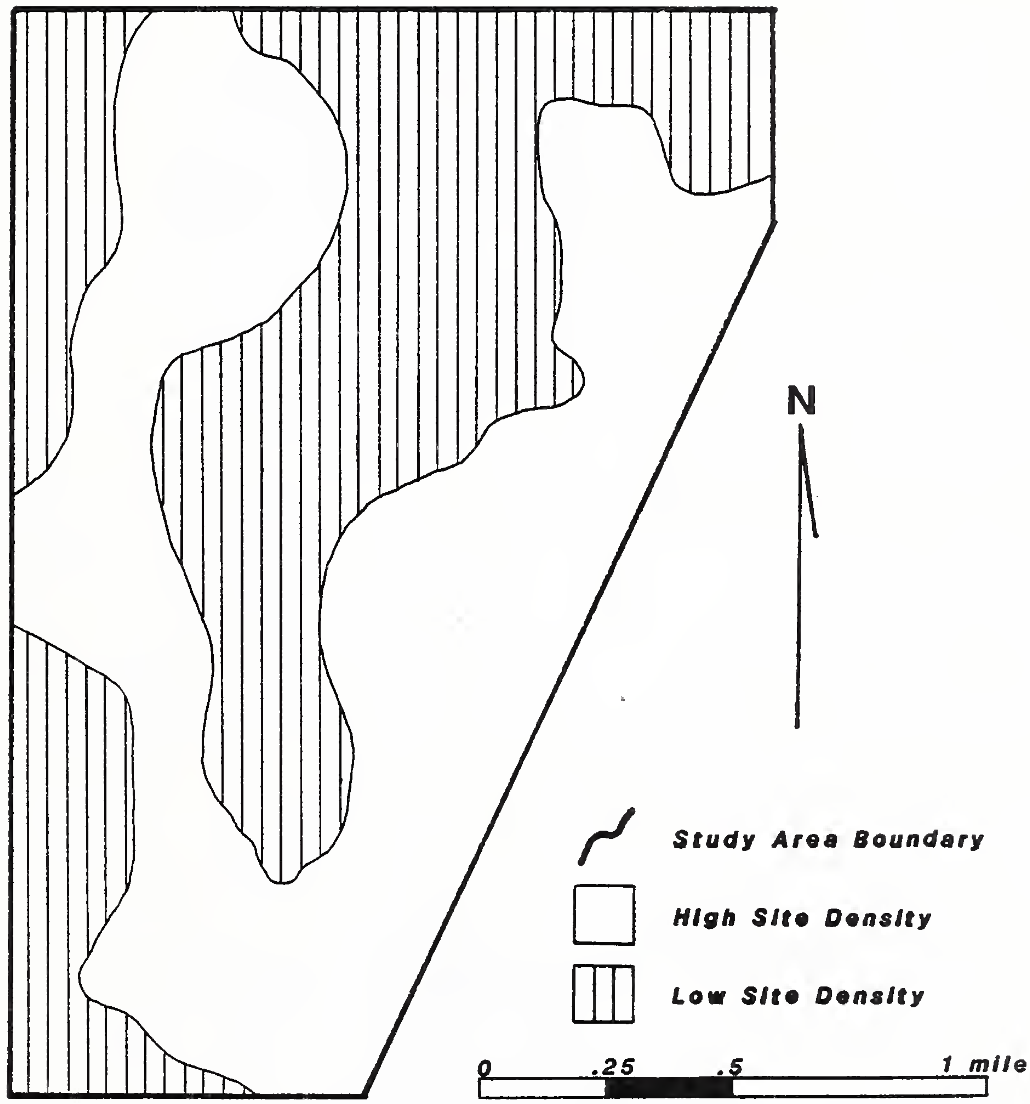
It is clear from this exercise that 95.1% of the sites located could have been found in surveying only 53.4% of the area (Figure 6). The strong tendency of the sites to cluster in portions of the area makes it feasible to attempt to determine environmental features that might allow the design of survey methods that can be directed to high density areas and away from areas of extremely low density.

### Description of Sites Excluded

In excluding just under one half of the area from survey, we have also excluded eight prehistoric sites from potential discovery. In examining these eight sites to discover their similarity to or difference from the other sites in the area, it might be possible to learn what variability in environmental or cultural attributes might account for their location away from the site clusters.

The eight sites excluded include three limited activity sites (ceramic and lithic scatters), three single room field houses, and two multi-room sites, the largest of which contains six rooms. The eight sites range from 875 to 1250 A.D. in median date of occupation. Of the three limited activity sites, two are lithic and ceramic scatters and one is a single storage cist. The single room field houses represent an early (875 A.D.) occupation, a late (1250 A.D.) occupation, and one of unknown age.

The multi-room sites date from the middle of the range of sites in the study area (950-1050 A.D.) and only one represents what is defined as a "village." Site #698, with six visible rooms, is located on the upper reaches of Allen Creek and is within




Map 5. Study Area, Manti-LaSal National Forest

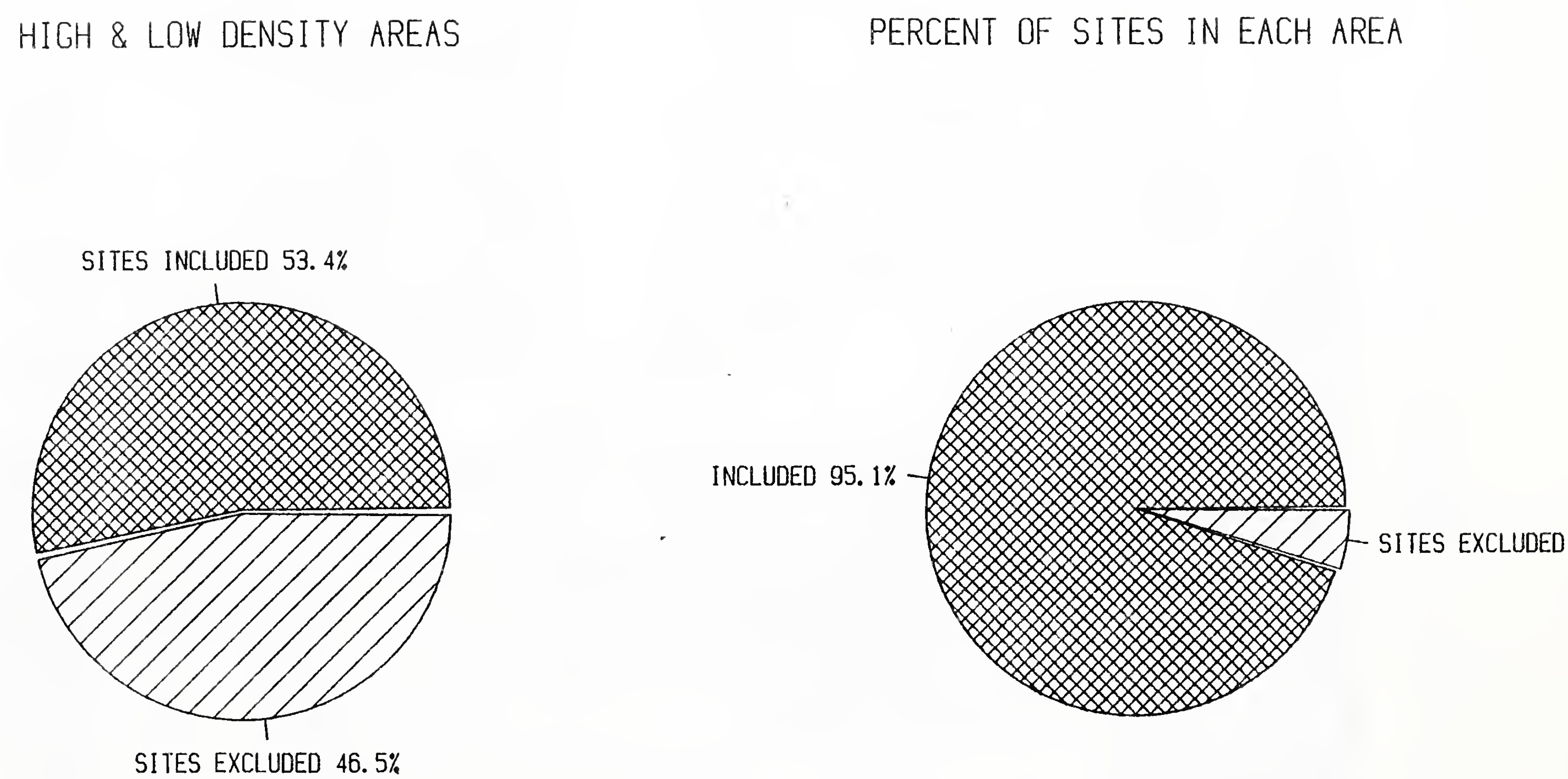



Figure 6. Site Occurance by Area, Study Area 5

250 feet of the creek. It is also located 1600 feet west of the Bayles Ranch spring and on a ridge that flanks the southern edge of the drainage fed by this spring.

Site #661 is a multi-room field house located near the center of the area exluded for lack of sites. It is located on the west facing slope of the central ridge that divides the study area into two drainage systems. Ceramics found are sparse (26-50) and show two occupational periods. The site is 400 feet west of a saddle in the central ridge and 500 feet east of a small draw that branches off from Allen Creek.

### Locating Excluded Sites

All of the sites excluded from the "major" site areas could have been located by two systematic survey methods. First, a survey of the permanent stream that included 500 feet on each side of the creek would have included sites #698, 728, and 729. A survey of the low ridges that extend at right-angles from the major drainage would have located sites #673, 674, 659, and 651. Only site #661 would have been missed by both of these approaches. It is possible that the ridge survey, if extended to all ridges in the study area, would have located site #661. This is problematic since the site is some distance from the ridgeline and there are other major ridgelines in the study area that contain very low site densities. Surveying all ridges would produce low results for relatively high effort.

## ENVIRONMENTAL ATTRIBUTES

In examining the characteristics of the sites located during the survey, a number of environmental and cultural attributes appeared to have some potential for determining the choice of site locations. Other attributes showed little if any distinction from site to site. Of those attributes with nonrandom distributions, the following were examined:

| | |
|---|---|
| Vegetation | Site Use |
| Landform | Site Type |
| On-site Topography | Site Size |
| Site Aspect | Surface Room Count |
| Mean Slope | Storage Cists |
| Elevation | Water/Soil Control Features |

The major difficulty in examining environmental variables for this area was the absence of such data. Maps of soils, vegetation zones, topographic units, etc., were not available. As a result, the analysis had to be limited to information on the site forms.

Vegetation recorded in each site shows that 87% of the sites occur in Pinyon-juniper forest, while the remainder occur in Juniper forest. Since there are no data on the distribution of these types for the area, it is impossible to determine the relevance of this attribute on site location.

Landform categories suggested the preference for colluvial valley deposits with 42% of the sites so located (Figure 7). Ridgetop sites were the next most frequent landform choices (29%) with Hill slopes and Canyon rim location next with 11.7% each. Once again, the absence of good soils and geomorphic data makes it difficult to assess these coorelations. The concentration of sites in the easternmost drainage of the unit, however, represents the major distribution of colluvial deposits.

Collapsing the landform categories from eight to three, shows a 54.3% share of sites in valley locations, 32.1% in ridgetop locations, and 13.6% on hillslopes.

On site topography shows a strong tendency to select for the flattest available land and geological features that, presumably, possess the greatest potential for horticulture. Of the eight different topographic features on which sites were found, the colluvial valley location was the most dominant (Figure 7). Low ridges, particularly in Allen Canyon, were the next most common site location. Steeper slopes of hills were also utilized, however, these sites were in the minority and represent high percentages of limited activity sites.

A comparison of topographic features by elevation suggests that colluvial valley deposits occur and were occupied at all but the lowest section of the study area (Figure 8). The greatest variety of occupied topographic features occurs in the mid-ranges of elevation where the colluvial deposits are the largest. Allen canyon possess only a limited amount of such deposits and, hence, there is a much higher percentage of ridge top and hill slope sites.

Site aspect shows a strong orientation to south and southeasterly directions with a lesser occurrance of southwesterly facing locations (Figure 9). The northerly oriented sites are by far a minority and a close examination of the types of sites found in these locations is warranted. It is clear from the topographic map of the study area that northerly orientations were possible in far greater numbers than were selected. It is also true that a majority of the area has a southerly to southeasterly exposure, and even a random distribution of sites would result in more sites with that orientation. An analysis of the percentages of available orientations would be useful in evaluating this distribution of locations.

An examination of mean slope at each site shows a high occurance of sites on slopes of less than 7% (86%) and a low occurance of sites on slopes greater than 9% (7%). Once again there are no data on the proportions of slopes of these ranges for the area, although it is clear that the steeper slopes do not contain an equal number of sites (Figure 10).

Elevation of the area ranges from 6200 to 7000 feet. Plotting site occurances by elevation shows a nearly normal distribution with 6600 feet as the mean (Figure 11). Comparing this distribution to a random number of elevation points (Figure 12) clearly shows the non-random nature of this distribution. Computing the percentage of the area in five elevation zones of 100-foot intervals allows us to compare the amount of available area at each elevation and the percentage of sites found there. Looking at this distribution (Figure 13) one can see that:

1. Very few acres above 7000 feet are available in the study area and no sites are found there.

2. Although there is a greater amount of area available at 6800 to 7000 feet, fewer sites are present as a percentage of area available.

3. Elevations between 6400 and 6800 feet contain about equal proportions of sites to area available.

4. More sites are found in the 6200 to 6400 elevation zone than would be expected given the percentage of area available.

Although there is considerable range of elevation in the study area, it is unlikely to be the major factor in site location. In spite of the correlation of sites to

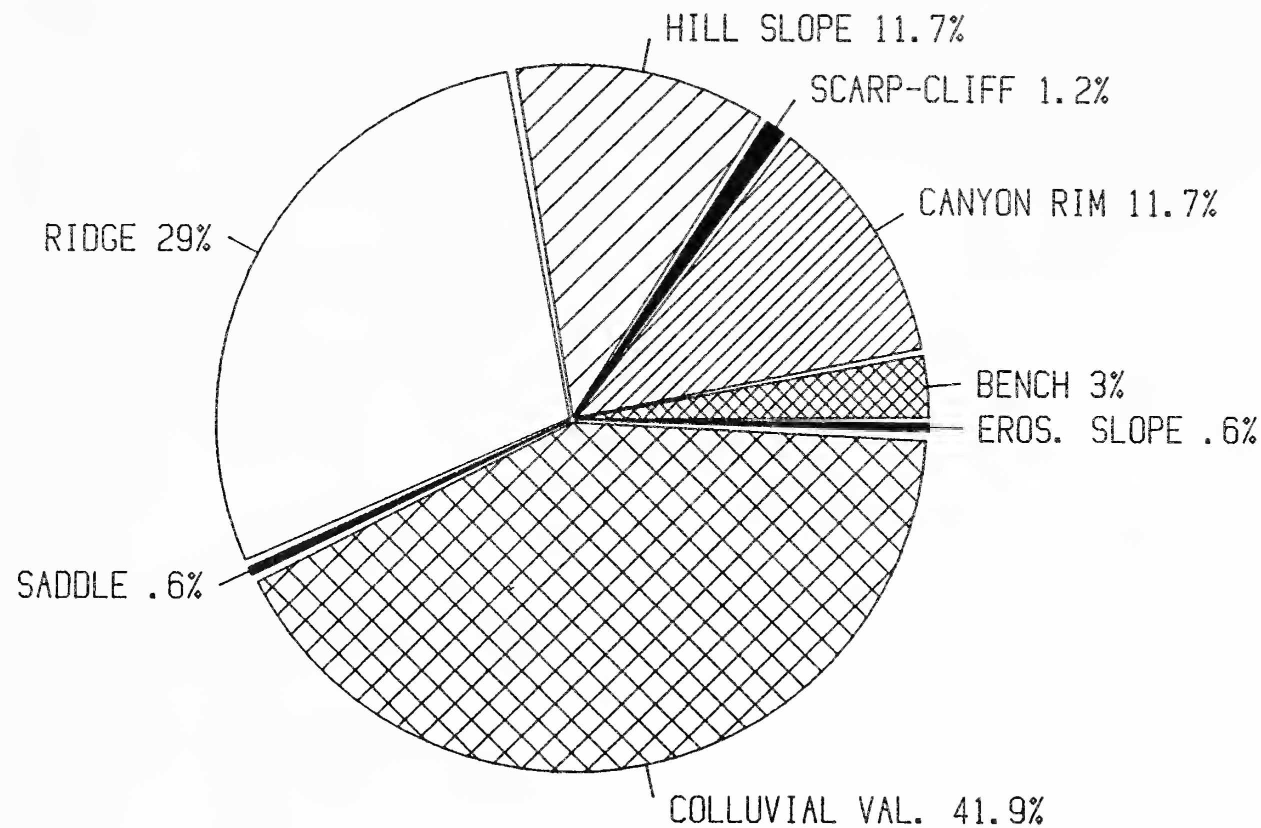



Figure 7. Landform Categories, Study Area 5

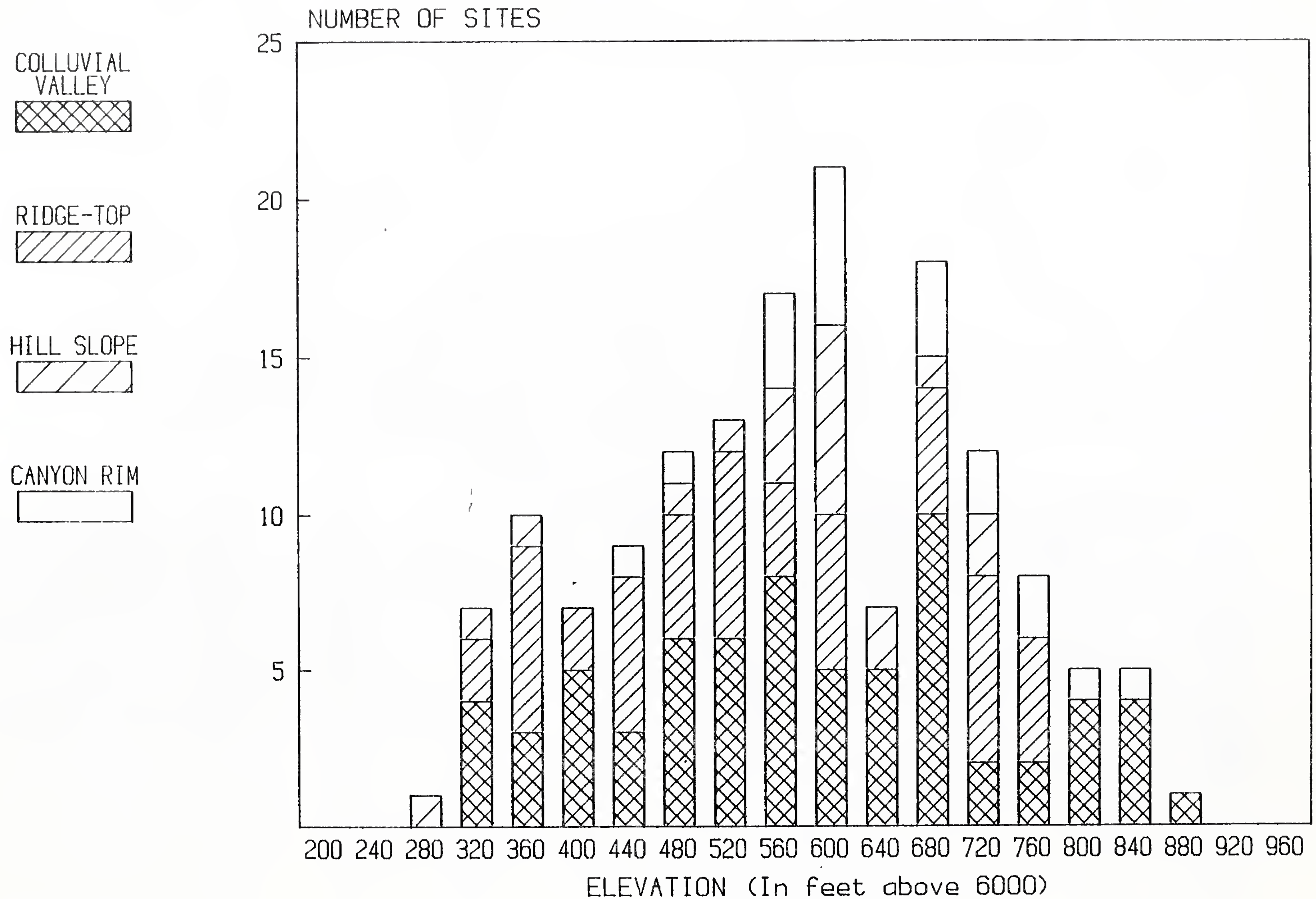



Figure 8. Site Topography by Elevation, Study Area 5

elevation zones, it appears clear that the availability of arable soils and relatively flat ground are more important. A comparison of the availability of these factors by elevation zone would be useful in determining the nature of this correlation.

At the extremes of the area it might be possible that elevation plays a role in the numbers of sites present. At high elevations outside of the survey area, few sites are found even though there are larger areas of gentle slope and southern exposure available.

## Comparison of Site Types by Area

Of the 162 sites in the study area, eight are described as villages. These contain from six to seventeen surface rooms (Figure 8). Two of these represent the largest sites in the study area, one in each of the drainages (Figure 9). The remaining village sites, each with from six to eight rooms are distributed two in Allen Canyon and four in the eastern canyon. All three of the Allen canyon village sites were tentatively placed at 1050 A.D. (median date) while the village sites in the eastern canyon range in median dates from 875 to 1250 A.D.

The remaining sites in the area represent a variety of single room field houses and limited activity sites. Allen Canyon appears to have been utilized a greater percentage of the time for collecting and gathering activities as 42.4 percent of the sites found there represent limited activities as compared to 29.5 percent for the remainder of the area. A comparison of other types of sites between the two drainages shows a higher percentage of fieldhouse sites in the eastern area but about the same number of villages to other sites.

TABLE 4. Comparison of site types by area.

| Site Type | Allen Canyon | Eastern Area |
|---|---|---|
| Village | 5.1% | 6.4% |
| Field House | 52.5% | 64.1% |
| Limited Activity | 42.4% | 29.5% |

It appears from the distribution of sites in the study area that the eastern drainage possessed a greater capacity for occupation than did the narrower Allen Canyon. It also appears from the ceramic dates that Allen Canyon was most heavily utilized in the middle of the 11th Century while utilization of the eastern part of the area began earlier and continued later in time. The reason for this likely lies in the greater availability of arable land in the broader colluvial deposits of the drainage.

From the examination of a variety of environmental variables, it appears that slope, aspect and the presence of farmable ridges and colluvial valley soils are the most highly correlated with site location. The correlation with arable soils must remain conjectural at the present time, due to the absence of soils information. It is possible from the contour maps and past experience in the area to present such an hypothesis, however, further investigation is necessary. Survey oriented to valley bottom, both sides of permanent streams and gently sloping, south facing ridges would have identified the majority of sites in the area. Those sites that fall outside of this strategy appear to be largely limited activity sites. One or two deserve closer examination to determine whether or not current descriptions of their nature and function are adequate. Their location in areas unlike the majority of other sites suggest some unusual circumstances might have resulted in their occurrance.

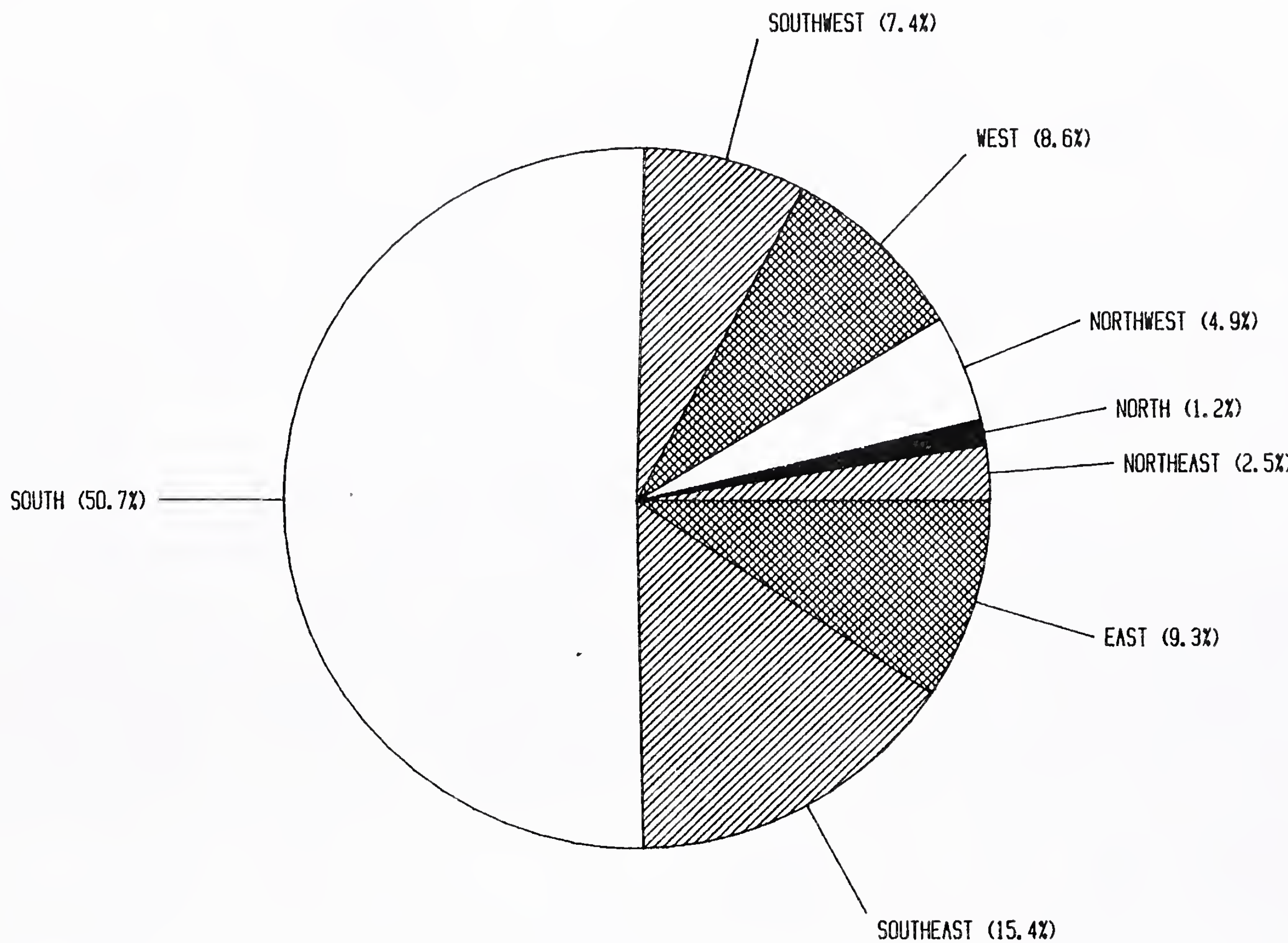



Figure 9. Site Aspect, Study Area 5

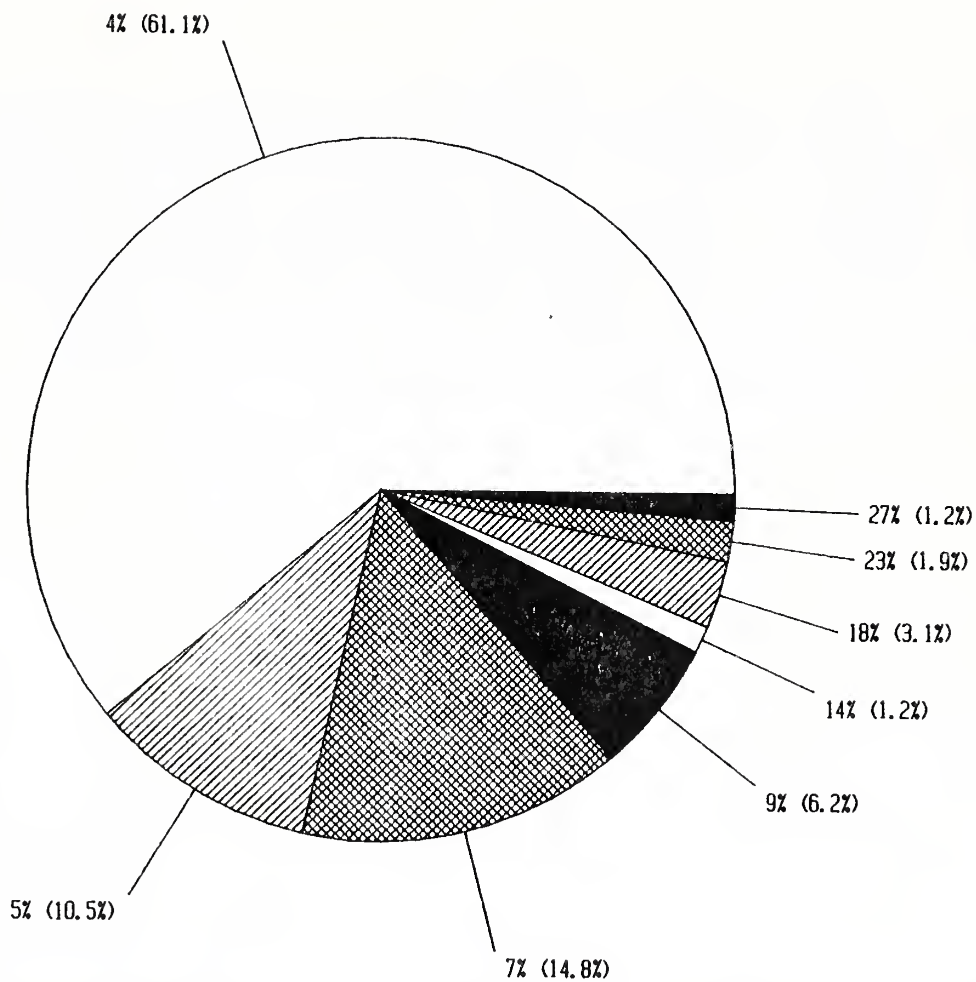



Figure 10. Mean Slope at Sites, Study Area 5

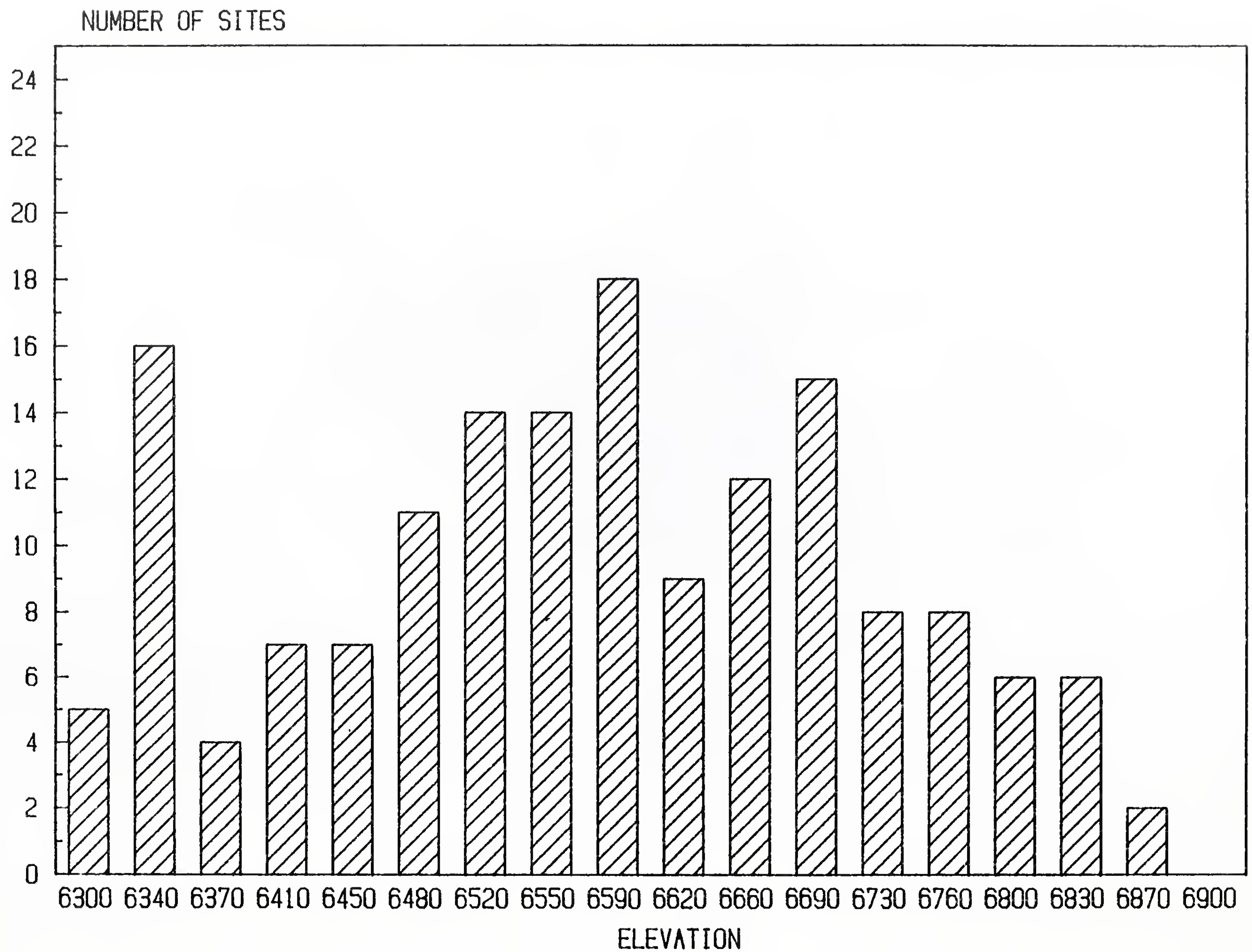



Figure 11. Number of Sites by Elevation, Study Area 5

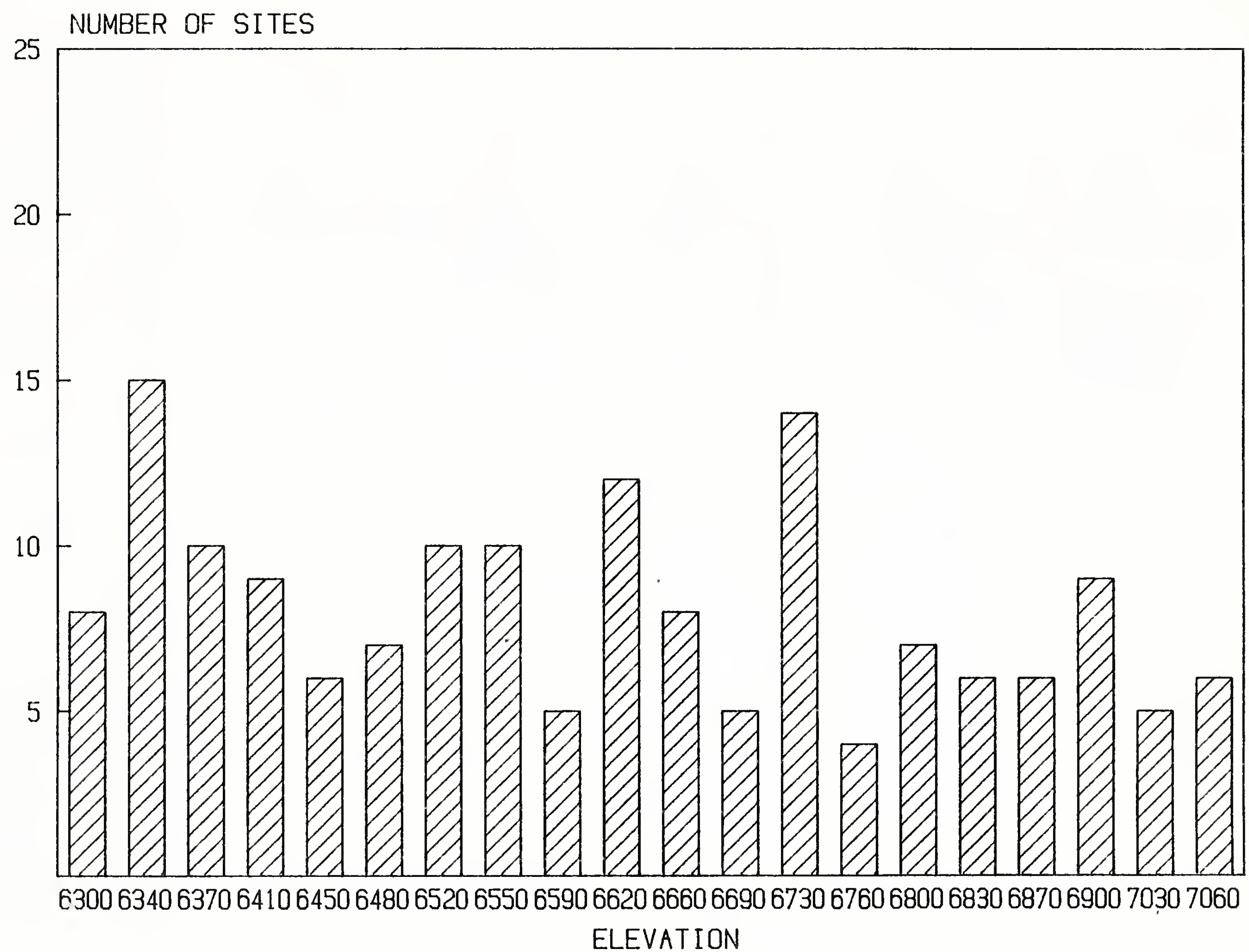



Figure 12. Random Elevations, Study Area 5

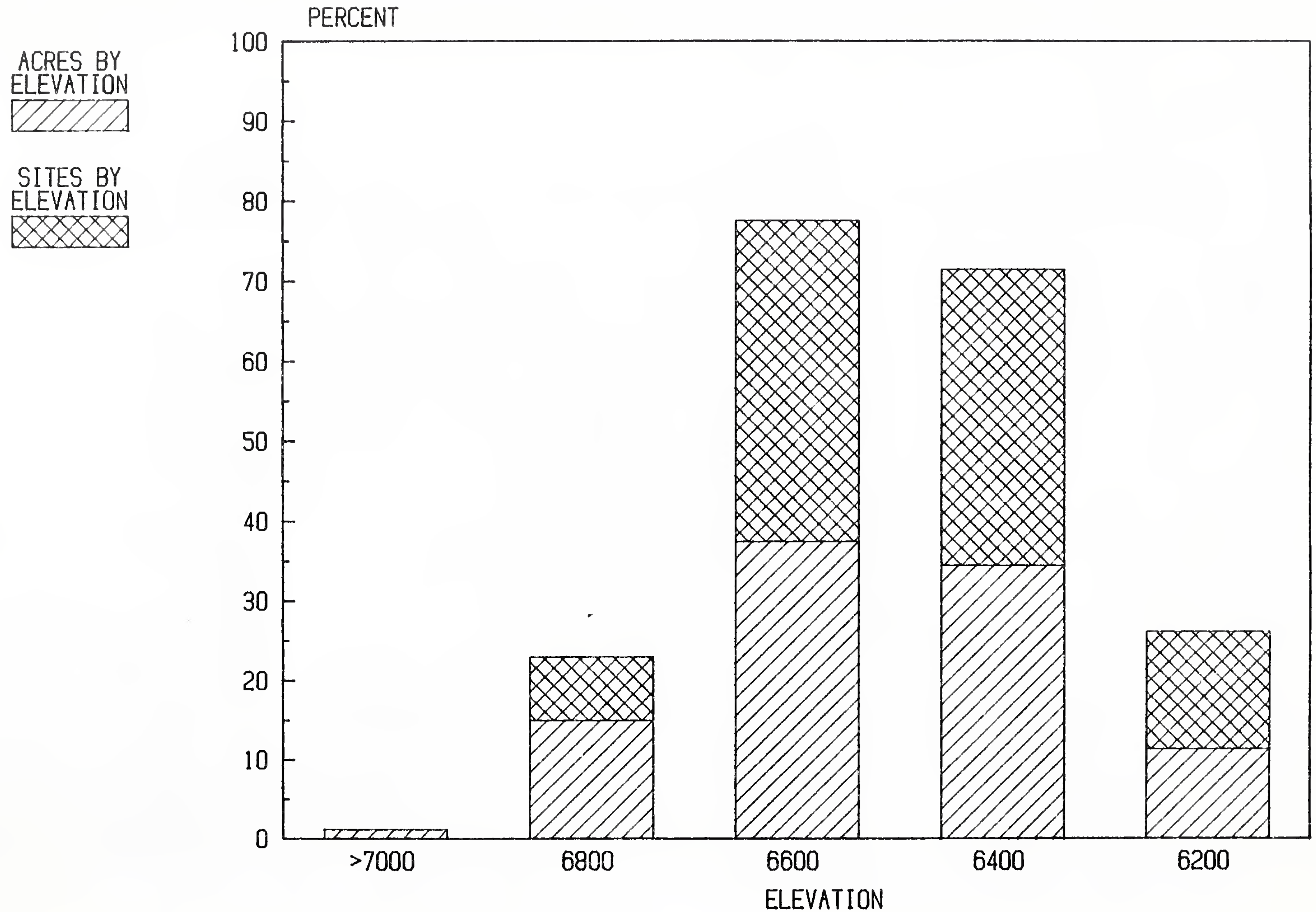



Figure 13. Percent of Sites by Elevation, Study Area 5

## PROCEDURES AND COMMENTS

The major problem faced in the analysis of the Allen Canyon study area was the paucity of environmental data beyond that recorded for each site. Maps of soils, vegetation zones, and geological features would have been of major help in the analysis. Color aerial photographis would also have been useful. Although the information collected in the 1971 survey provided considerable data to examine, its orientation specifically to individual site locations makes it impossible to examine locations where sites were not found and to determine what environmental factors existed in areas not prehistorically utilized.

Another concern in preparing this analysis was the limited size of the area. It is clear from the site information that the area was not heavily occupied. Even though the sites are frequent and densities are high, the predominant site types is a single room field house, followed by a variety of limited activity sites. It is likely that this small drainage was but a peripheral area to a larger cultural system that might be centered lower down the drainage beyond the National Forest boundaries. Similar systems appear to have developed in other parts of the area where very large multi-storied pueblos are found along the major drainages and numerous small sites are found around them at the higher elevations.

In summary, it appears that a survey strategy could be developed to identify the large majority of prehistoric sites in the study area while at the same time reducing the area surveyed by up to 50%. It would be useful to take the environmental attributes identified here and apply them to other areas of Elk Ridge that have been surveyed. Work done on Milk Ranch Point would appear to confirm these observations, although no equivalent analysis of that area has been performed. The 1973 survey of nearby Cotton wood Canyon would also be an excellent study to examine in the light of this model.

It is urgently clear that the standard survey procedures being applied in the Forest Service leave a great deal to be desired as far as the application of the data collected to the analysis of environmental characteristics. If future attempts to refine survey strategies are to be more successful, more attention must be paid to the collection of supporting environmental data and the periodic evaluation and analysis of these data.

# STUDY AREA 6: JEMEZ DISTRICT, SANTA FE NATIONAL FOREST

Dee F. Green

## DESCRIPTION

The study area comprises 3758 acres at elevations from 6080 to 7520 feet located in Township 17 North Range 3 East on the Jemez Ranger District, Santa Fe National Forest, New Mexico. The study area was surveyed as part of the Borrego Timber Sale by a trained crew of Forest Service Archeologists during the 1981 field season (Elliott 1981a, 1981b; Mills, 1981a, 1981b, 1981c). Coverage was complete and sites recorded on standard Forest Service forms. Both prehistoric and historic sites were recorded although only the prehistoric sites are considered in this study.

The study area is part of Borrego Mesa, an upland area on the southern edge of the Jemez Mountains. The area supports an open ponderosa pine forest with pinyon-juniper interspersed.

Culturally the area is dominated by 169 prehistoric sites dating between 1300 and 1600 A.D. The area contains two large pueblos estimated to have 750 and 400 rooms. There are seven sites of 4-10 rooms and 114 with 1-2 rooms. The remaining 46 sites consist of various special activity areas including agricultural features, sherd and lithic scatters, knapping areas, rock art, etc.

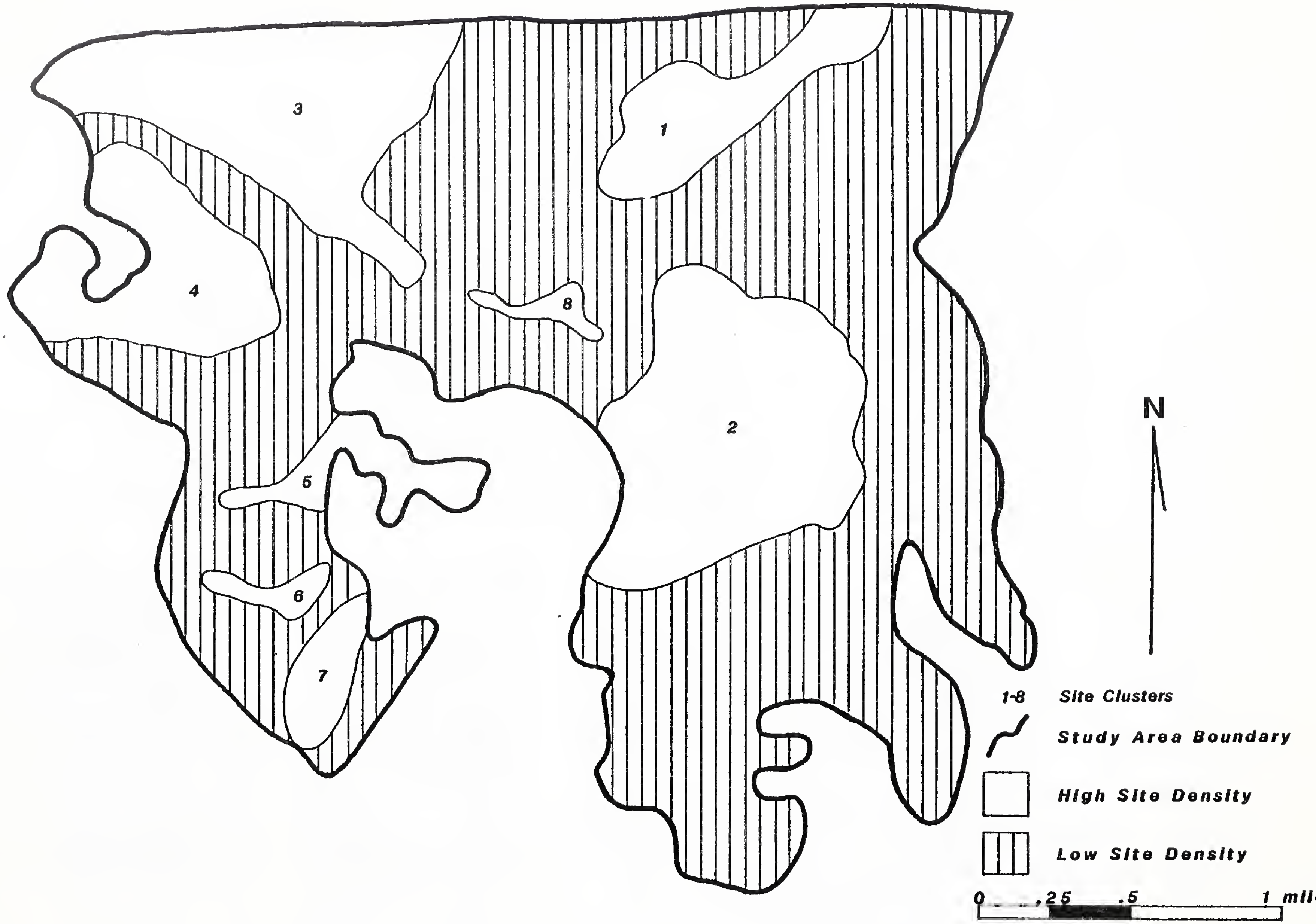
## LOW DENSITY AREAS

Map 6 shows the high and low site density zones for the study area. Inspection of the site map for the study area revealed that most of the sites are clustered on the landscape. The remaining areas have a low density of .006 sites per acre compared with the clustered areas where site density is .12 per acre. At this point the critical issue is whether the sites in the low density areas are similar or different from sites in clusters. If the sites are essentially redundant and no information would be lost then there is no need to survey the low density areas. The low density acreage is 2532 leaving a total of 1226 acres with sites out of the 3758 total acres of the project area.

## SITES OUTSIDE CLUSTERS

Cluster boundaries were drawy by simple visual inspection as a first cut. More sophisticated distance calculations should be employed when the real models are developed. Eighteen sites were located outside the clusters. The computer printout for these sites was then inspected to see if any of the sites were unique or materially different from similar sites in the population. One site (971) a soil/water control site has the most structures (15) in its class of sites. However, there are ten similar sites remaining in the cluster areas. No other site even approached having characteristics which set it apart from other sites in the population.

Figures 14, 15, and 16 show the percentages which each of the 18 sites constitutes for the total population based on three different variables. In no case does this exceed 18% and most are 11% or below. The reader is reminded that these observations are based on the description of surface observations only. Assuming that the observed redundancy of surface observations holds true for the subsurface areas, failure to find and record these sites would




Map 6. Study Area, Jemez Ranger District, Santa Fe National Forest

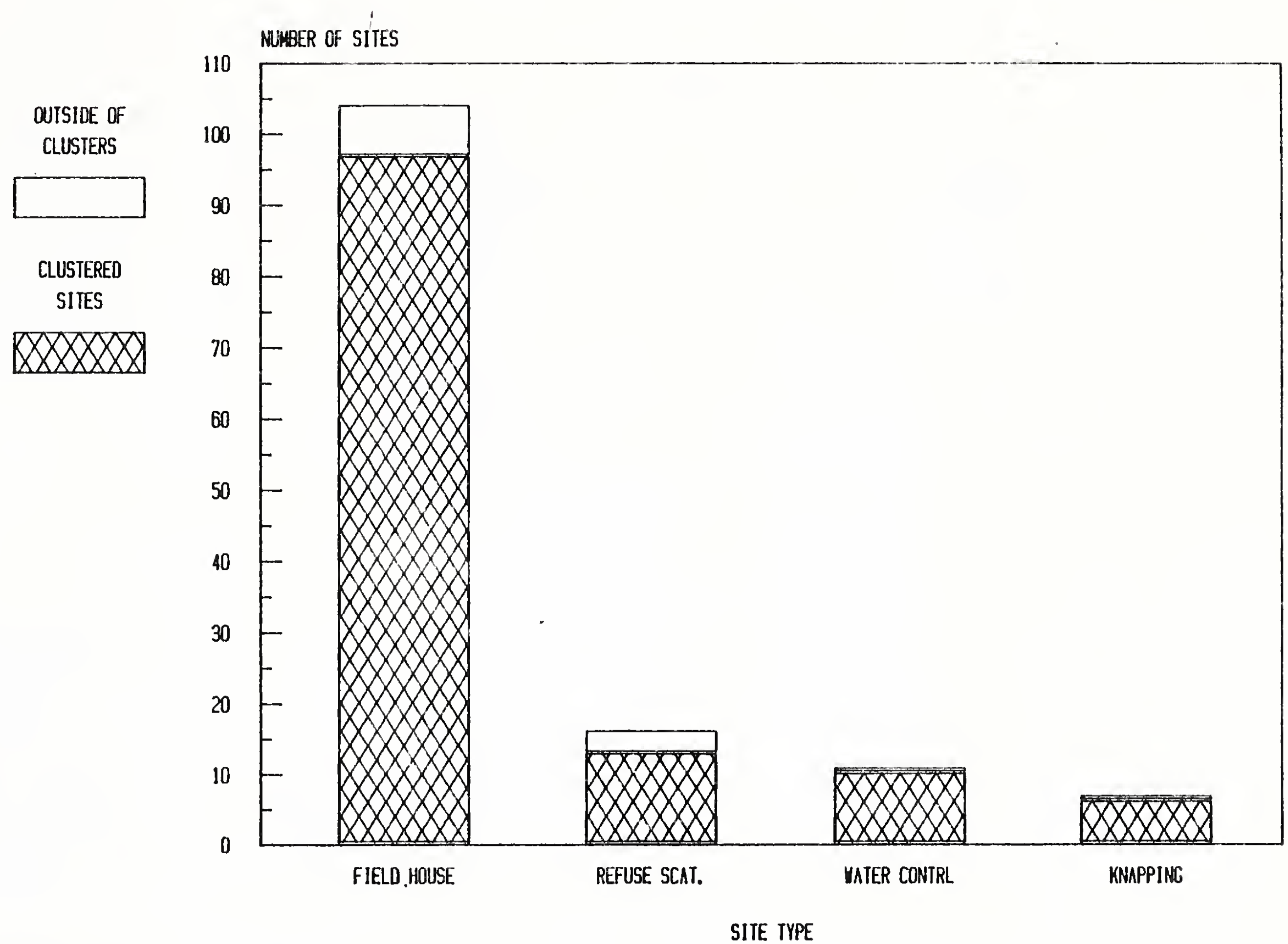



Figure 14. Percent of Sites Outside Clusters by Site Type, Study Area 6

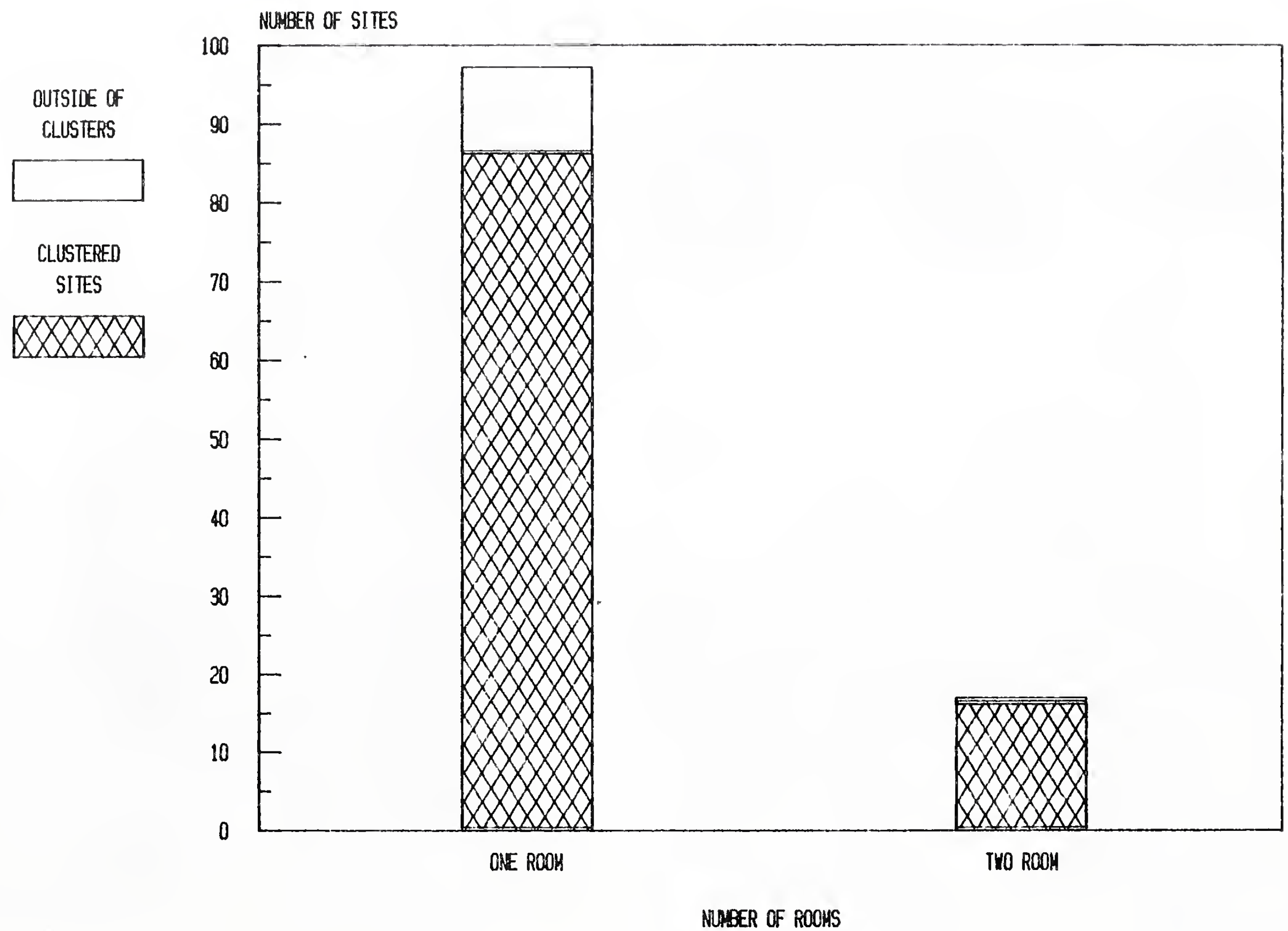



Figure 15. Percent of Sites Outside Clusters by Number of Rooms, Study Area 6

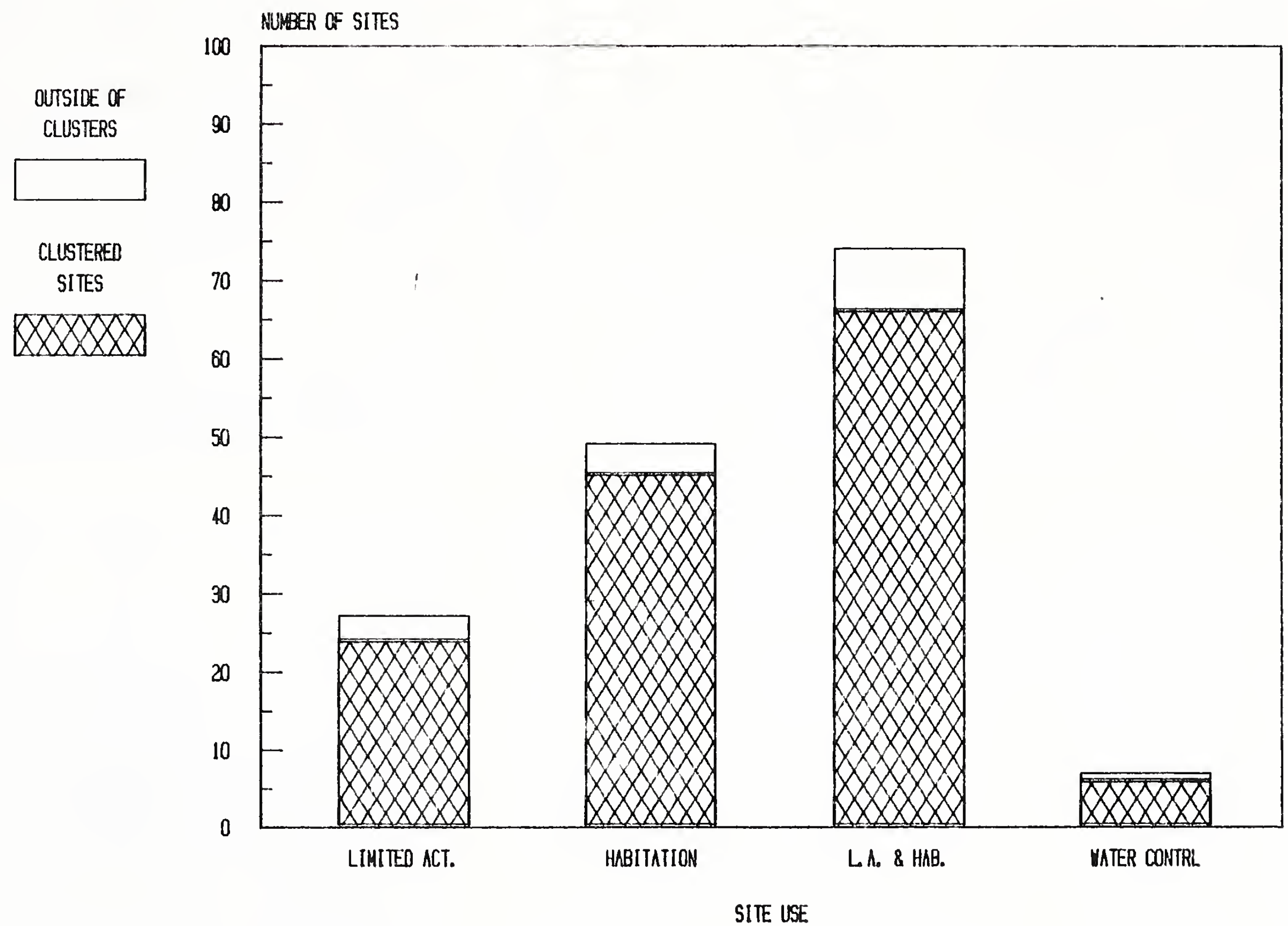



Figure 16. Percent of Sites Outside Clusters by Site Use, Study Area 6

not effect the knowledge base of the study area.

Given the observed differences between very high (clustered) site densities and very low site densities are there ways to predict where these may occur on the landscape? Locational differences could be accounted for on the basis of either environmental or cultural variables or both. I will now examine these two potential predictors of location.

## ENVIRONMENTAL VARIABLES

On the basis of SARG research (Euler and Gumerman 1978) it is thought that combinations of environmental variables are more productive in site locational analysis than are variables considered on an individual basis. Accepting this proposition I decided to examine the location of sites in the study area based on the Forest Service Terrestrial Ecosystem concept. The Terrestrial Ecosystems concept is based on the interplay of soils, climax, vegetation, and climate. Studies are produced for each ranger district which define a series of "mapping units" each of which is described in detail, given a number, and shown on a map. These data may be found in Gass and Price (1980). Table 5 shows the various mapping units for the study area with their characteristics of interest and the number of sites located on each unit.

Unit 612 has the best horticultural land in the study area as shown by the herbage and forage production units in Table 6. It also has the gentlest slopes and best

Table 5. Characteristics of Terrestrial Ecosystem Units in the Study Area.*

| Unit No. | Soils | % Slopes | Plant Available Water (IN) | Soil Depth (IN) |
|---|---|---|---|---|
| 126 | Udic Haplustalfs | 16-40 | .84-1.26 | 20-40 |
| 127 | Udic Ustochrepts | 41-20 | --- | 20-40 |
| 149 | Typic Eutroboralfs | 41-120 | --- | 60+ |
| 510 | Petrocalcic Paleustalfs | 0-15 | --- | 20-40 |
| 511 | Udic Argiustolls | 16-40 | .84-4.19 | 20-40 |
| 612 | Udic Haplustalfs | 0-15 | .46-1.35 | 40+ |
| 614 | Typic Ustorthents | 0-15 | 1.19-1.58 | 60+ |
| 631 | Typic Ustorthents | 16-40 | 1.19 | 60+ |
| 638 | Udic Haplustalfs | 0-40 | --- | 20-40 |
| 675 | Typic Eutroboralfs | 16-40 | .64-4.82 | 20-40 |
| 685 | Udic Haplustalfs | 16-40 | 1.39-4.13 | 20-40 |

*After Gass and Price 1980: Tables 1, 3, 6

Table 6. Herbage and Forage Production Potential for Selected Terrestrial Ecosystem Units.*

| Unit No. | Herbage Production Potential | Forage Production Potential |
|---|---|---|
| 126 | 500 | 300 |
| 127 | 350-550 | 250-450 |
| 149 | 450-650 | 150-350 |
| 510 | 300-500 | 200-350 |
| 511 | 700 | 350 |
| 612 | 750 | 400 |
| 614 | 650 | 300 |
| 631 | 550 | 300 |
| 638 | 500-700 | 300-400 |
| 675 | 500 | 250 |
| 685 | 500 | 300 |

*After Gass and Price 1980: Table 2.

moisture retention. All the sites located on this unit are either field houses or refuse scatters. Units 614 and 631 have the most site locations with the two large pueblos located one on each unit. The smaller pueblos (4-10) rooms are all located on Unit 614. A few sites are located on units 511 and 510, although the latter have not received much survey. All 18 of the sites which have been excluded lie on either 510, 511, 612, 614, or 631 units. It appears that these are the best predictors of site locations although units 510 and 511 need more acres surveyed. However, sites are not evely distributed over these units and there may be additional environmental variables within the mapping units which could assist in refining the prediction of locations. I suggest that a closer look at the soils and such things as slight elevation differences might be examined.

## CULTURAL VARIABLES

The cultural variables examined were site type, and room count. Figure 17 shows room counts. Clusters 2 and 5 are comprised of sites with only one or two rooms. clusters 1 and 4 have the very large pueblos with all other sites having no more than two rooms. Clusters 6, 7, and 8 each have sites with four, eight, and five rooms respectively. Cluster 3 has three sites with no more than two rooms. There are two with five and one with 10.

A comparison was made of the number of rooms in each cluster excluding the two large sites. Rooms per acre were calculated for each of the eight clusters as shown in Figure 18. The clusters are grouped rather than placed in numeric order to show relationships between certain clusters. The cluster 1, 3, 4 group are the areas with major acreage and high room counts. The cluster 6, 7, and 8 group are areas with low acreage and small room counts each containing a single site with more than two rooms. Cluster 5 lacks any site with more than two rooms. Cluster 2 has the lowest sites per acre with no rooms above two.

The next comparison involved sites with only one room. Figure 19 shows the rooms per acre. The same patterning of the clusters exists except for the 6, 7, 8 group where more variability exists and where group 8 has two sites with no rooms.

What Figures 18 and 19 suggest assuming relative contemporaniety of the sites, is that Clusters 1 and 4 represent aggregated populations in the two large centers with small domiciles in the neighborhood. Cluster 3 represents an area associated with Cluster 4 showing some site growth, but still dominated by one and two room units. Clusters 6, 7, and 8 are much smaller

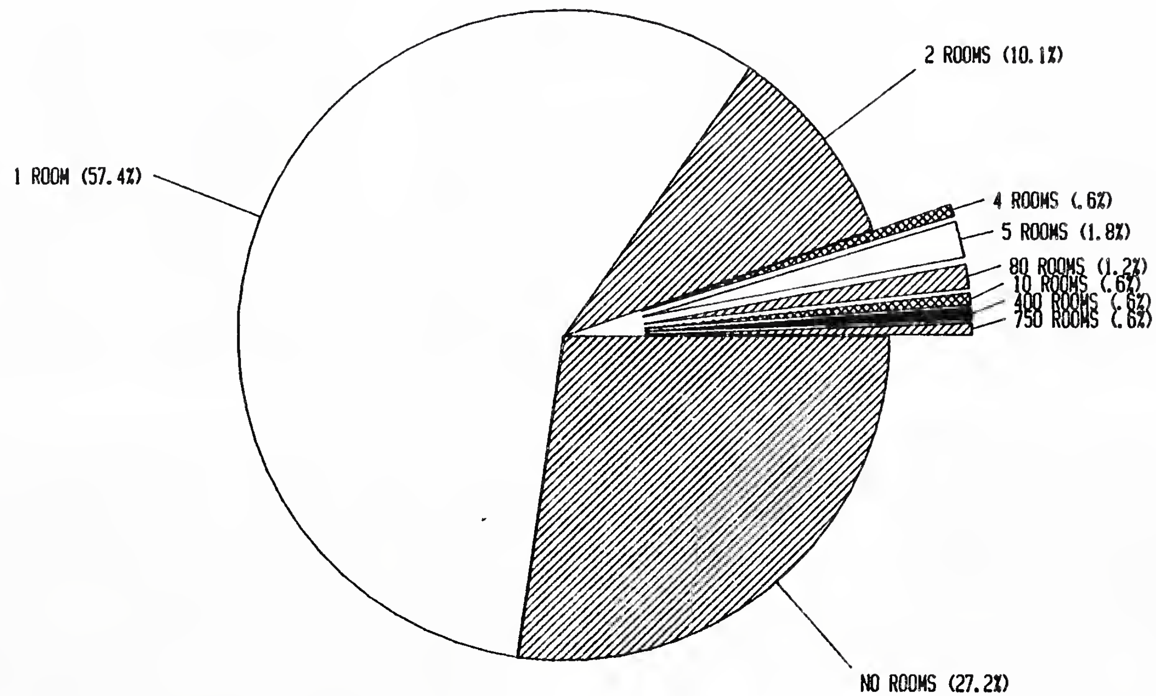



Figure 17. Rooms Counts, Study Area 6

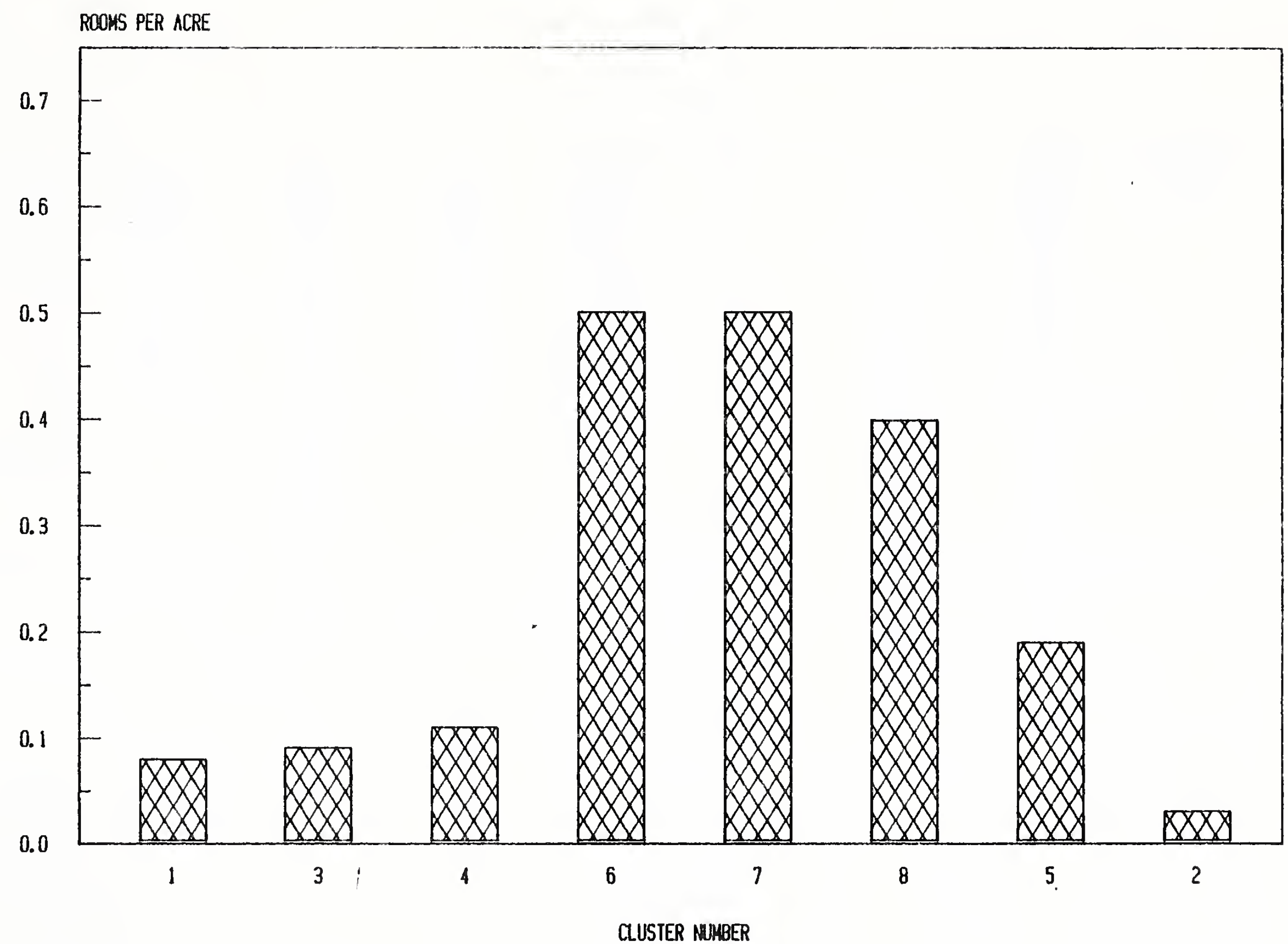



Figure 18. Rooms per Acre all but Large Sites, Study Area 6

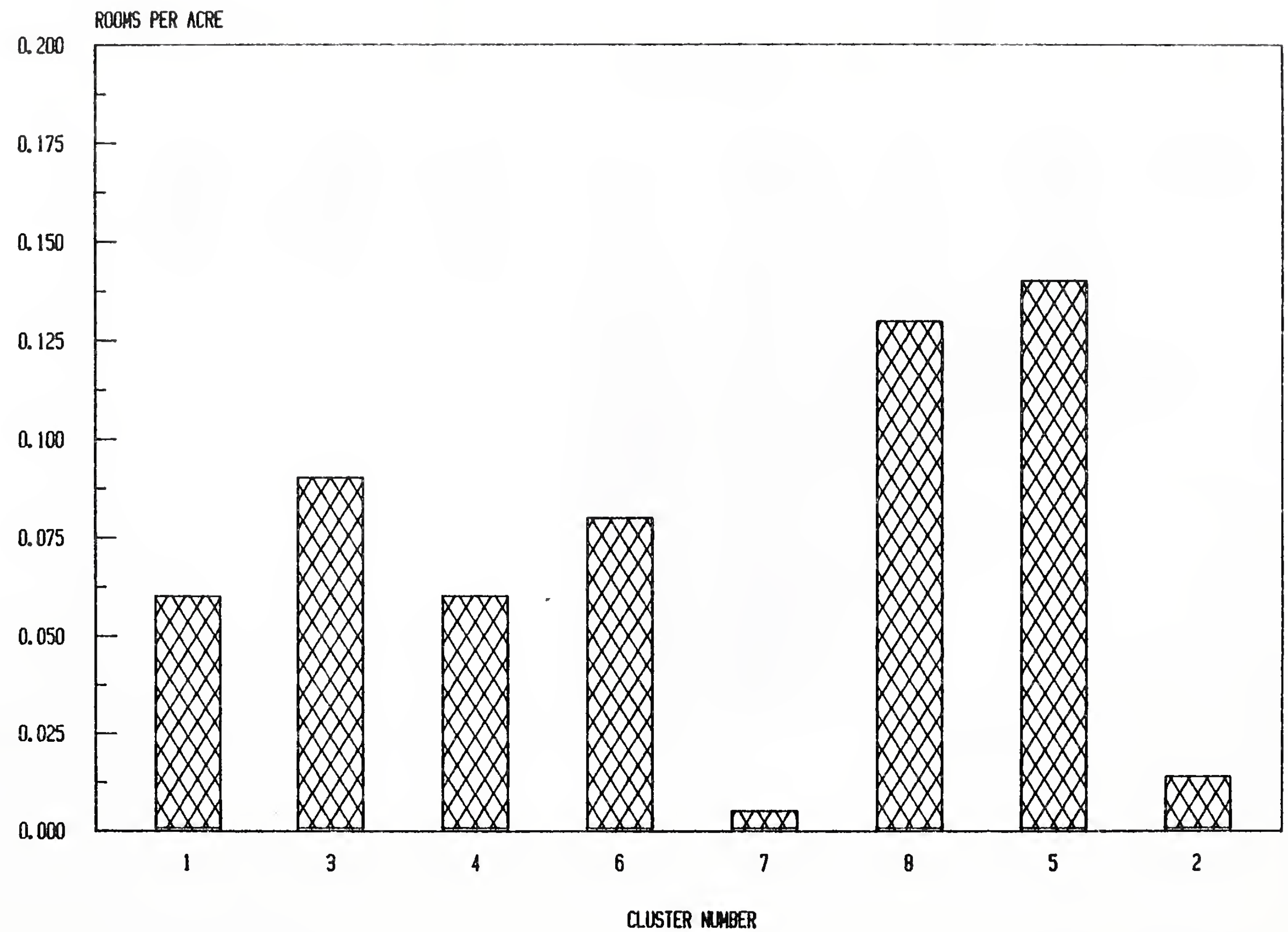



Figure 19. Rooms per Acre One Room Sites Only, Study Area 6

versions of Cluster 3 with 6 and 7 probably associated with Cluster 4 and 8 with Cluster 1 or 3. Cluster 5 is comparable in size to 6-8 but lacks the single larger site. Cluster 2 is a field area associated with Cluster 1. The location of all sites with more than two rooms on Unit 614 (except the 750 room site) and at distances from each other is probably a combination of the environmental variables working with a cultural pheonomena such as social distancing. The location of the 750 room site in a 631 unit probably cannot be accounted for without inventory data to the north, west and south, since the site is on the very western boundary of the project.

## ENVIRONMENTAL DEFINITION

Habitation sites (with four or more rooms) will tend to be located over most of the land surface of Unit 614. Sites with two or fewer rooms will be located predominately in Unit 614 with occurances in Units 510, 511, 612, and 631. In Unit 612 only a small percentage of the land will contain sites. Soil-water control sites will be located in unit 614. Unit 631 will contain habitation sites but in lesser quantity than Unit 614. Where units 614 and 612 occur with common boundaries any class of sites will have a greater tendency to be located in unit 614. The above assumes a "patchy" distribution of the units. Areas where units have considerable acreage, especially 612 and 614 may have similar patterns.

There are other areas on the Jemez District where this model could be tested using already existing archeolgical data and mapping units.

## GENERAL THOUGHTS

I am optimistic that predicting zones for site locations using the Terrestrial Ecosystem can work. We need a refining of quantitative techniques, and more careful mapping than was available at the conference, in order to shift from a trial model to a working model.

# STUDY AREA 7: CORONADO NATIONAL FOREST

Paul R. Fish

## DESCRIPTION

Study Area 7 is a portion of the larger Northern Tucson Basin survey area (Fish, Fish and Madsen 1983) (Map 7) and has been selected to illustrate aspects of prehistoric settlement variability in the basin and range topographic province typical of broad segments of the Coronado National Forest. The study area is bounded by the Tortolita Mountains to the north and by the Tucson Mountains to the south. These ranges help define the Tucson Basin physiographically and contribute to the exploitable environmental diversity for its inhabitants. To the south and east, boundaries are based on the division between heavily developed residential and industrial land and relatively less modified acreage. A total of 102 square miles fall within the study area.

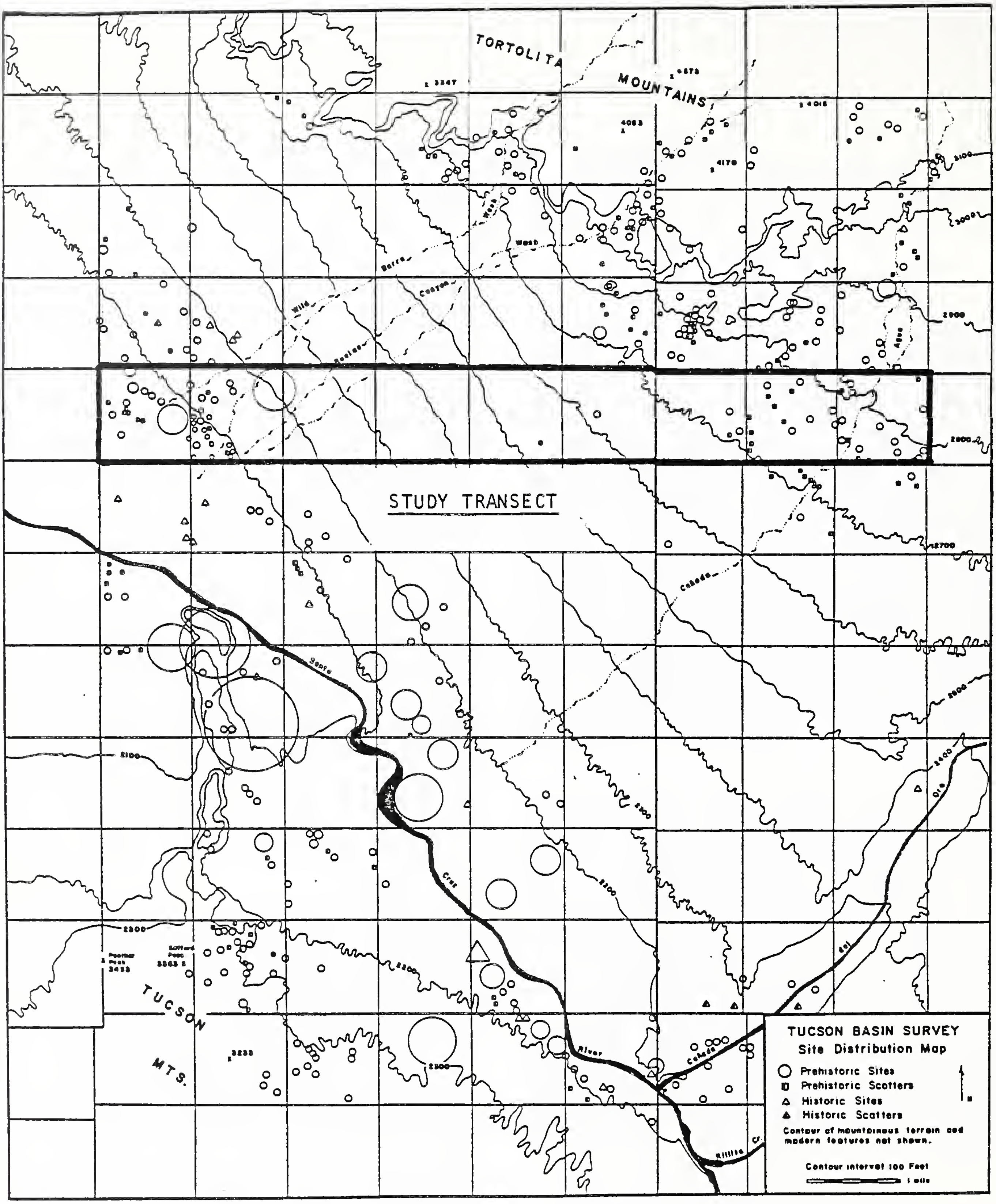
The study area shares many environmental characteristics with Lower Sonoran Desert basins in general. It is a broad alluvial valley bounded by rugged mountains. Located at the eastern edge of the Sonoran Desert, the climate is semi-arid and is characterized by year around warm temperatures, sunny days and scant rainfall. The survey area was designed to include a full range of topographic situations found in desert basins. Foothills and mountains surrounding the basin, bajadas and interior flats, as well as terraces and floodplains of the Santa Cruz and lesser drainages were included.

## DATA BASE

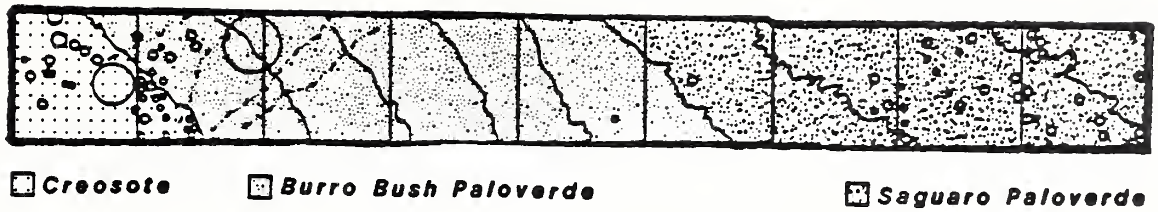
A total of 313 prehistoric archeological sites, hundreds of artifact scatters, and thousands of isolated artifacts were recorded by intensive survey of the entire study area. Localities designated as sites range from small scatters of 25 or more artifacts covering only a few hundred square meters to huge ballcourt villages encompassing as much as 4,000,000 square meters. Remains assignable to Hohokam and Archaic manifestations were identified and the range of site types includes several kinds of settlements, quarries, agricultural fields, villages, and extractive/processing areas.

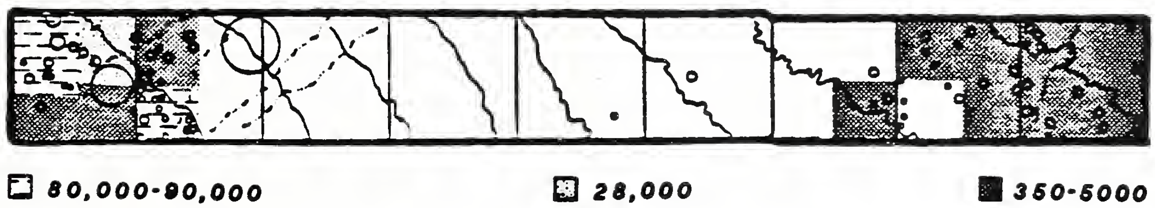
The survey was intensive, with field crew members spaced 30 to 40 meters apart. With the exception of approximately 12 square miles of industrially and residentially developed land, the entire study area was surveyed. Environmental information was recorded at both site and quarter section levels. In this study, the quarter section serves as the unit of integration of environmental measures and allows comparisons of cultural response to combinations of characteristics.

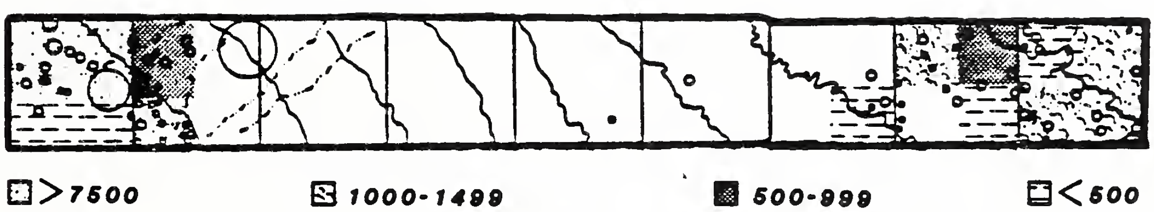
Prelimary analysis of distributional data suggests stability in settlement pattern from Late Archaic/Pioneer Period Hohokam through the Hohokam Classic Period. The most obvious feature of this site distribution is a clear pattern in the northern part of the study area in which small dispersed upland settlements hug the edges of the Tortolita Mountains and the larger villages are located in the creosote flats of the lower bajada and alluvial valleys (Map 8a). The adjacent zone displays an almost complete lack of prehistoric utilization. However, the bajada areas between the Santa Cruz and Tucson Mountains are

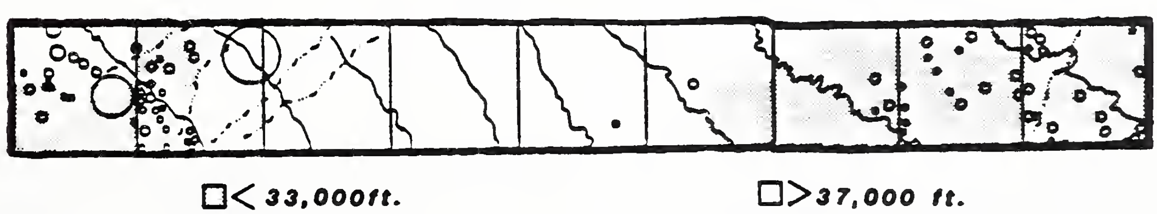



Map 7. Tucson Basin Survey




Map 8. Environmental Variables and Site Distributions: a. major or vegetation associations; b. Distribution of habitation site area per quarter sections; c. distribution of average habitation site size per quarter section; d. total class III-IV drainage length.

greatly compressed and a similar distribution is not apparent.

## DATA SET

A one mile wide transect extending nine miles from the Santa Cruz alluvial valley to the Tortolita Mountains provided an opportunity to examine environmental factors influencing the upland/lowland dichtomy in settlement. A total of 49 sites were recorded in this transect. With one exception, all sites belong to the Hohokam archeological culture. Unfortunately, only 40% can be placed within more refined chronological phases, and these are limited to the Sedentary and Classic periods. Nearly all sites in the sample appear to indicate some form of habitation locality, based on the diversity of artifact types and density of remains on the surface. However, few cultural features are visible on the surface. More detailed environmental and cultural characteristics of the data subset are presented by quarter section in Table 7.

## SITE DISTRIBUTION

Prehistoric remains in the sample subset are almost exclusively restricted to the lowermost portion of the lower bajada and the uppermost part of the upper bajada. Map 8b,d shows the high and low site density zones for the study area. Of the 5760 total acres, one contiguous block of 3040 acres, or 57% of the total, is almost totally devoid of sites. A single exceptional site is a small concentration of flaked stone debris of unknown age and cultural affiliation; an isolated scatter (25 artifacts) in this block is the remains of a single broken pottery vessel. Likewise, fewer than 10 isolated artifacts per

Table 7. Detailed Environmental and Cultural Characteristics by Quarter Section, Study Area 7.

| TOWNSHIP | RANGE | SECTION | QUARTER SECTION | NO. OF SITES | NO. OF SCATTERS | NO. OF ISOLATED ARTIFICATS | HABITATION SITE AREA-M$^2$ | OTHER SITE AREA-M$^2$ | MAXIMUM ELEVATION | AVERAGE SLOPE | SLOPE RANGE | VEGETATION ASSOCIATION | MAJOR LANDFORM | CLASS III & IV DRAINAGE FT. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11S | 12E | 31 | NE | 3 | 4 | 31 | 28900 | | 2130 | 4 | 4 | Creosote | Terrace/ Bajada | 49,400 |
| | | | NW | 4 | | 76 | 86000 | | | | | Creosote | Terrace/ Bajada | 43,000 |
| | | | SE | 2 | | 20 | 375 | | 2090 | 4 | 4 | Creosote | Terrace/ Bajada | 30,800 |
| | | | SW | 2 | | 49 | 800 | | 2060 | 4 | 4 | Creosote | Terrace/ Bajada | 13,000 |

Table 7. Continued

| TOWNSHIP | RANGE | SECTION | QUARTER SECTION | NO. OF SITES | NO. OF SCATTERS | NO. OF ISOLATED ARTIFICATS | HABITATION SITE AREA-$M^2$ | OTHER SITE AREA-$M^2$ | MAXIMUM ELEVATION | AVERAGE SLOPE | SLOPE RANGE | VEGETATION ASSOCIATION | MAJOR LANDFORM | CLASS III & IV DRAINAGE FT. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 32 | NE | 1 | | 0 | | 2,000,000 | 2240 | 4 | 8 | Burro Brush -Paloverde | Lower Bajada | 45,000 |
| | | | NW | 6 | 1 | 39 | 5175 | 400 | 2180 | 4 | 4 | Creosote/ Burro Brush -Paloverde | Lower Bajada | 29,400 |
| | | | SE | | | | | | 2180 | 4 | 4 | Burro Brush -Paloverde | Lower Bajada | 50,400 |
| | | | SW | 12 | 2 | 40 | 83430 | | 2140 | 4 | 4 | Creosote | Terrace/ Bajada | 46,800 |
| | | 33 | NE | | | 4 | | | 2360 | 4 | 4 | Burro Brush -Paloverde | Lower Bajada | 54,000 |
| | | | NW | | | 0 | | | 2300 | 4 | 4 | Burro Brush -Paloverde | Lower Bajada | 46,800 |
| | | | SE | | | 3 | | | 2320 | 4 | 4 | Burro Brush -Paloverde | Lower Bajada | 59,400 |
| | | | SW | | | 4 | | | 2260 | 4 | 4 | Burro Brush -Paloverde | Lower Bajada | 49,200 |
| | | 34 | NE | | | 2 | | | 2500 | 4 | 4 | Burro Brush -Paloverde | Lower Bajada | 49,400 |
| | | | NW | | | 2 | | | 2420 | 4 | 4 | Burro Brush -Paloverde | Lower Bajada | 48,000 |
| | | | SE | | | 5 | | | 2460 | 4 | 4 | Burro Brush -Paloverde | Lower Bajada | 51,600 |
| | | | SW | | | 2 | | | 2380 | 4 | 4 | Burro Brush -Paloverde | Lower Bajada | 52,300 |
| | | 35 | NE | | | 4 | | | 2640 | 4 | 4 | Burro Brush -Paloverde | Lower Bajada | 45,000 |
| | | | NW | | | 2 | | | 2580 | 4 | 4 | Burro Brush -Paloverde | Lower Bajada | 43,800 |
| | | | SE | | 1 | 7 | | | 2575 | 4 | 6 | Burro Brush -Paloverde | Lower Bajada | 47,800 |
| | | | SW | | | 3 | | | 2520 | 4 | 4 | Burro Brush -Paloverde | Lower Bajada | 51,500 |

Table 7. Continued

| TOWNSHIP | RANGE | SECTION | QUARTER SECTION | NO. OF SITES | NO. OF SCATTERS | NO. OF ISOLATED ARTIFICATS | HABITATION SITE AREA-$M^2$ | OTHER SITE AREA-$M^2$ | MAXIMUM ELEVATION | AVERAGE SLOPE | SLOPE RANGE | VEGETATION ASSOCIATION | MAJOR LANDFORM | CLASS III & IV DRAINAGE FT. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 36 | NE | 1 | | 21 | | 200 | 2720 | 6 | 10 | Saguaro -Paloverde | Upper Bajada | 37,300 |
| | | | NW | | | 6 | | | 2660 | 4 | 8 | Saguaro -Paloverde | Upper Bajada | 43,200 |
| | | | SE | | | 4 | | | | 5 | 6 | Saguaro -Paloverde | Upper Bajada | 41,600 |
| | | | SW | | | 14 | | | 2620 | 4 | 6 | Saguaro -Paloverde | Upper Bajada | 30,600 |
| 11S | 13E | 31 | NE | 1 | | 21 | | 380 | 2760 | 4 | 4 | Saguaro -Paloverde | Upper Bajada | 28,800 |
| | | | NW | | | 0 | | | 2760 | 4 | 4 | Saguaro -Paloverde | Upper Bajada | 20,400 |
| | | | SE | 1 | 1 | 13 | 600 | | | 4 | 4 | Saguaro -Paloverde | Upper Bajada | 30,700 |
| | | | SW | | | 5 | | | 2700 | 4 | 6 | Saguaro -Paloverde | Upper Bajada | 28,800 |
| | | 32 | NE | 3 | 1 | 14 | 3245 | | 2820 | 4 | 4 | Saguaro -Paloverde | Upper Bajada | 18,000 |
| | | | NW | 1 | 2 | 27 | 900 | | 2780 | 4 | 4 | Saguaro -Paloverde | Upper Bajada | 21,000 |
| | | | SE | | 2 | 3 | 2200 | | 2100 | 4 | 4 | Saguaro -Paloverde | Upper Bajada | 21,000 |
| | | | SW | | 4 | 7 | | | 2740 | 4 | 4 | Saguaro -Paloverde | Upper Bajada | 19,200 |
| | | 33 | NE | | 1 | 5 | | | 2860 | 4 | 6 | Saguaro -Paloverde | Upper Bajada | 16,800 |
| | | | NW | 4 | 1 | 32 | 1125 | 100 | | 4 | 4 | Saguaro -Paloverde | Upper Bajada | 29,400 |
| | | | SE | 4 | 3 | 22 | 5170 | | 2820 | 4 | 4 | Saguaro -Paloverde | Upper Bajada | 24,600 |
| | | | SW | 4 | | 33 | 4180 | | 2780 | 4 | 4 | Saguaro -Paloverde | Upper Bajada | 33,000 |

square section were identified in this 3040 acre block and most of these isolates were rolled and tumbled sherds originating from sites on the upper bajada.

## ENVIRONMENTAL VARIABLES NOT SENSITIVE FOR SITE PREDICTION

An evaluation of the distribution of soil types was not illuminating because of extreme variability within the narrow nine mile transect. A broader study area that would allow an opportunity to certain collapse types for purposes of analysis might offer greater potential for correlation. Average slope and range in slope proved to not be useful because of their lack of variability. Slope averages four degrees without significant departure across the entire bajada.

## ENVIRONMENTAL VARIABLES SENSITIVE FOR SITE PREDICTION

### Elevation

The bimodal distribution of site frequency by elevation illustrated in Figure 20 and contrasted with a random distribution in Figure 21 demonstrates an extremely strong association between site locations and two elevation ranges. On the upper bajada, only one site falls below the 2700 foot contour; this is the small lithic scatter referred to previously. Maximum site elevation on the lower bajada is 2200 feet, leaving a 500 foot elevation gap with little evidence of prehistoric utilization.

In the Tucson Basin, temperature inversion has significant elevational effects and this offers a possible explanation for the tight clustering of small habitation sites above the 2700 foot contour. The impact of cold air flowing downslope is illustrated by five years of weather records for a station on the shoulder of Tumamoc Hill (2760 foot contour) and for a second station on the plain below near the Santa Cruz River (Hastings and Turner 1965: 17). The stations were separated by only one-half mile and 300 feet of elevation. A difference of 20 degrees was recorded on some nights. Over the five years, the average number of freezing nights on the hill were 38, versus 263 on the floodplain. The frost-free period between first and last freezes for a winter averaged 36 days on the hill and 157 below. Low temperatures were of shorter duration on the hill as well.

### Drainage Length

In order to assess preference for drainage types, width classes were chosen for observation rather than traditional sequential count of drainage order beginning with the largest. It was felt that width might better relate to opportunity for water control and acquisition. The total length of channels in each four width categories was calculated by quarter section (Map 8d).

Lengths of the two narrowest categories (Class III and IV) were combined and a histogram displaying the frequency of quarter sections in 5000 feet increments was prepared (Figure 22). Using the resulting bimodal distribution, two categories of quarter sections were defined; one of drainage lengths of less than 33,000 feet and one with lengths greater than 37,000 feet. With only two exceptions quarter sections with drainage lengths of less than 33,000 feet percisely covary with the distribution of habitation sites in the study unit. The exceptions are located at the juncture of the river terrace and the lower bajada.

Measurement of drainage length may be an index of stream entrenchment. Only 1:20,000 scale aerial photographs are uni-

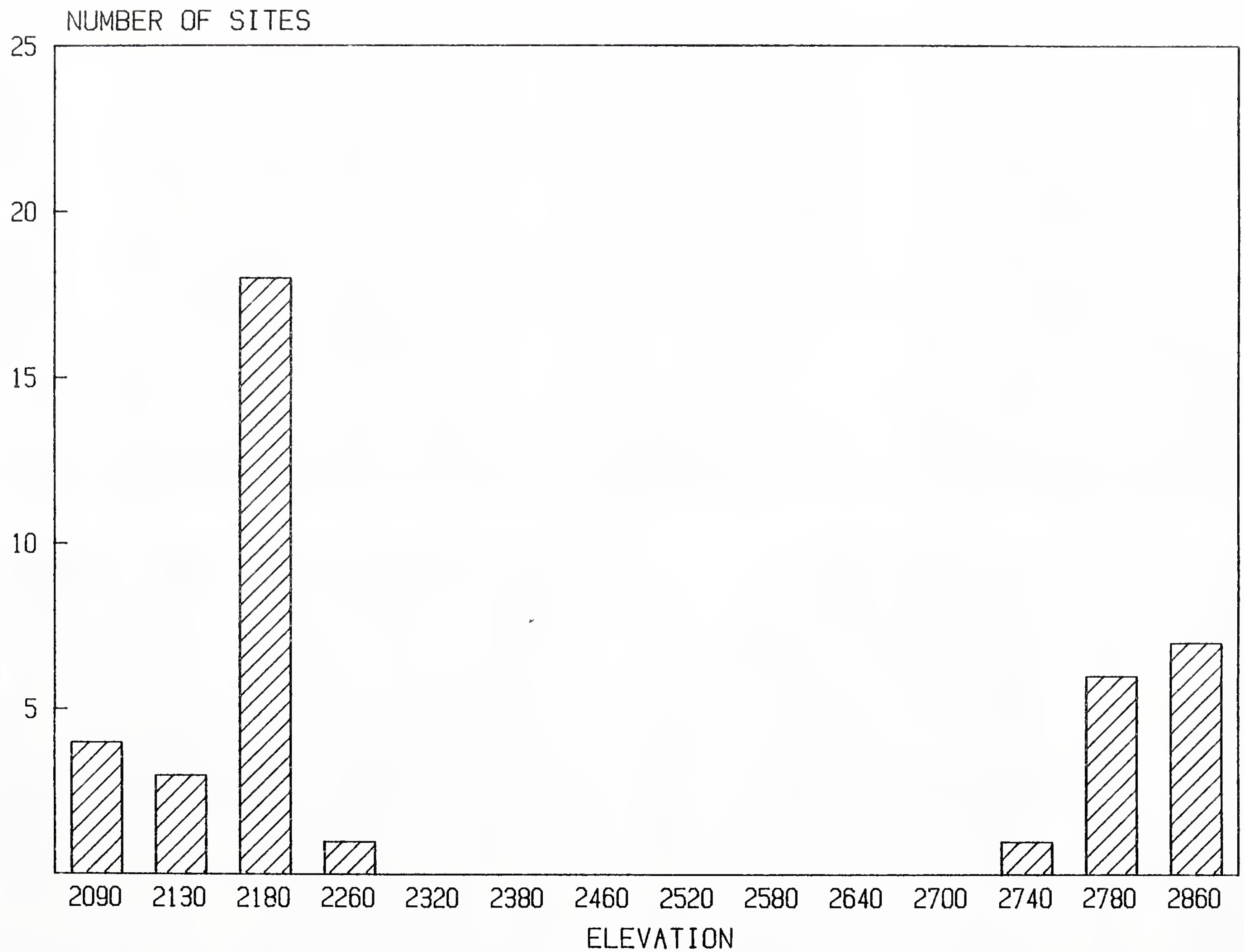



Figure 20. Site Frequencies by Elevation, Study Area 7

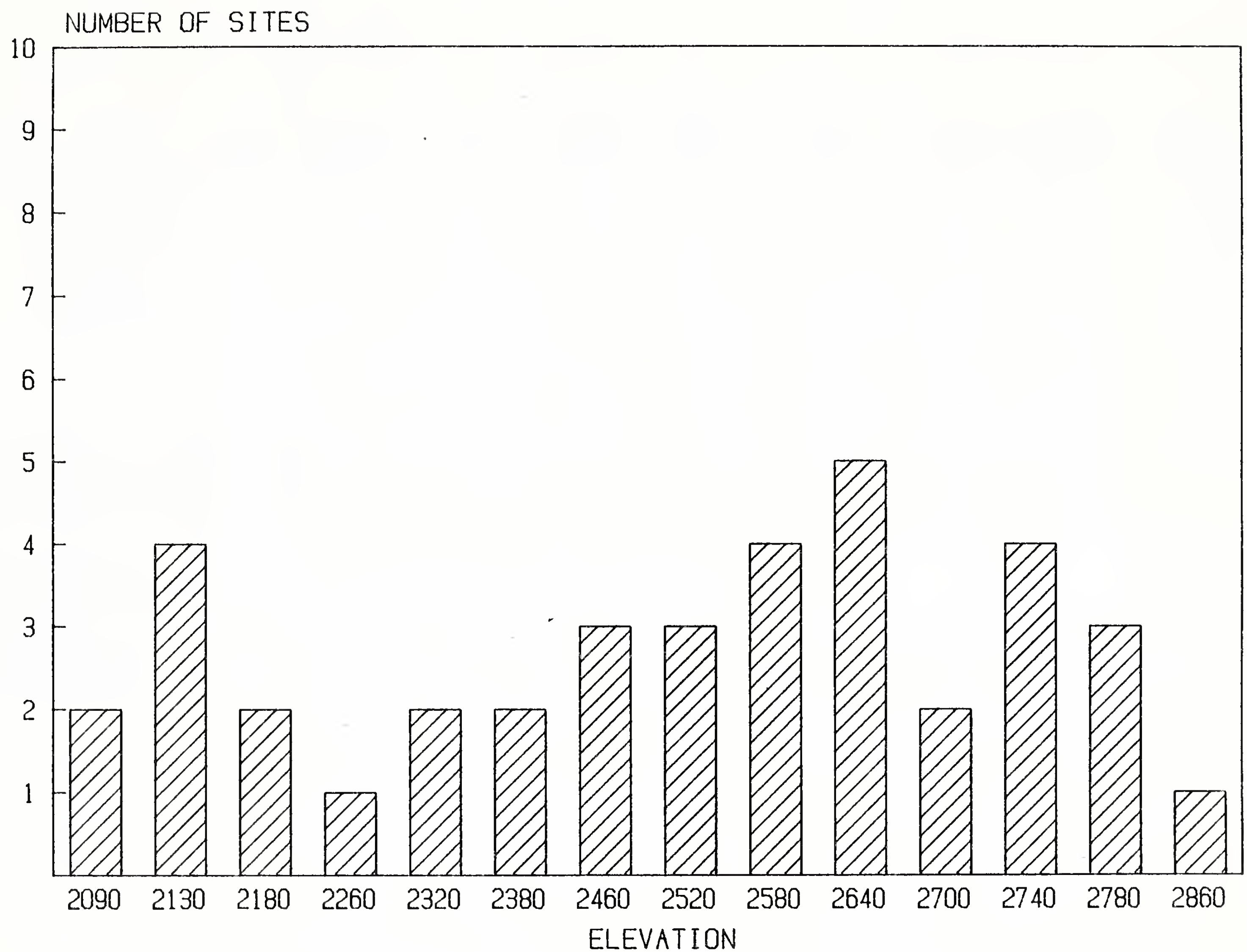



Figure 21. Site Frequencies by Random Elevation, Study Area 7

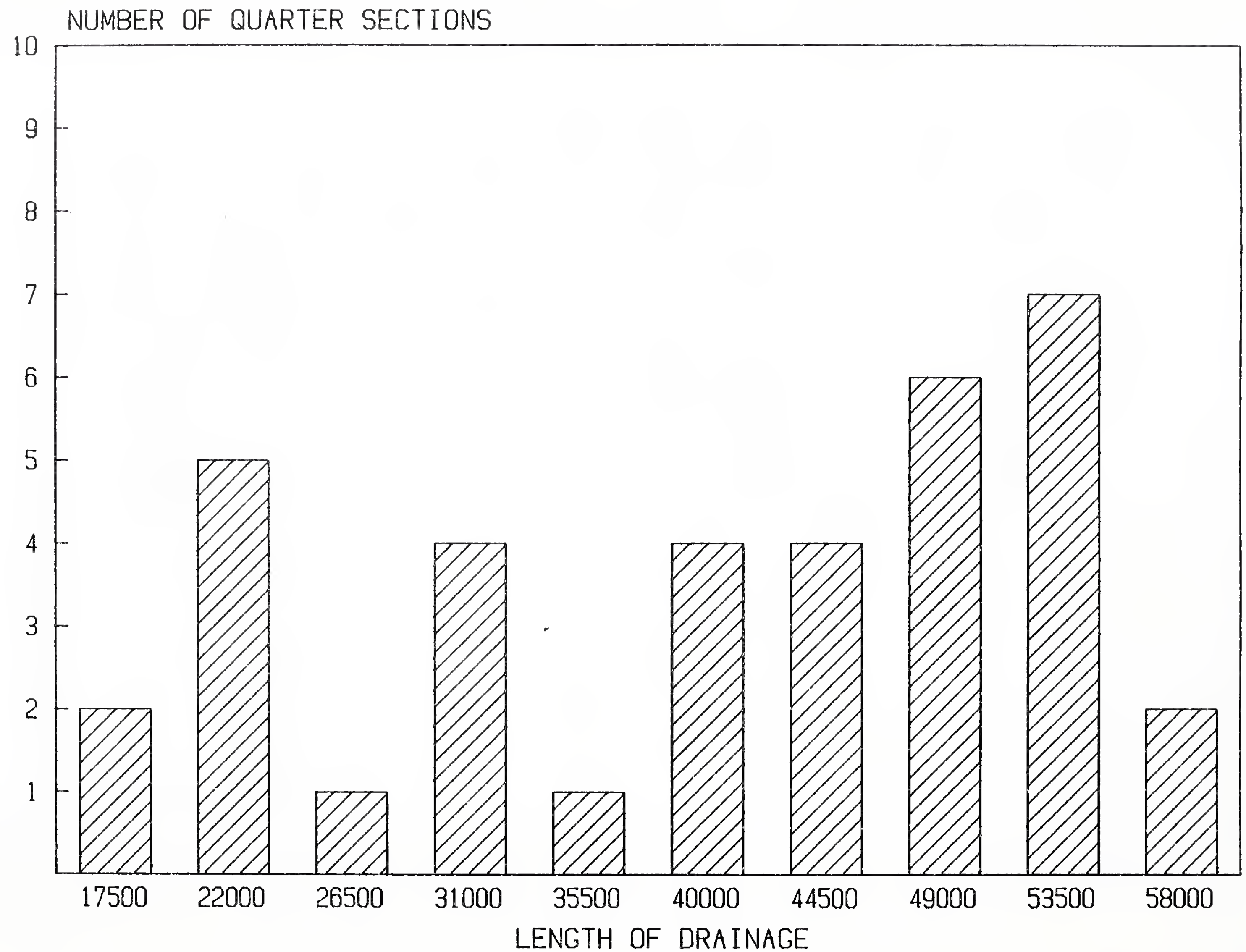



Figure 22. Drainage Length of Class III and IV Quarter Section, Study Area 7

formly available for the larger study area and this scale was used to make drainage calculations. Small channels at points of braiding were simply not visible on the photographs.

Valley fill forming bajada slopes in the Tucson Basin is generally deep. Areas of channel restriction in the form of igneous intrusions of indurated beds are infrequent, because as slope angles decrease over deep fill, drainages become less well defined, with localized shifting and braiding. Such points, where streams are less entrenched and the channel divides, would provide the easiest opportunities to control and direct floodwaters for agricultural purposes would be optimal.

## IMPLICATIONS FOR CULTURAL RESOURCE MANAGEMENT

The most glaring deficiency in regional archeological knowledge for the southern deserts is information pertaining to the kinds, frequencies, and distributions of sites for any time horizon or areal segment. While there has been a notable upsurge in research dealing with the region, these studies have almost uniformly occurred under the constraints of contractual obligations. These restrictions have focused research on narrow linear transects or on particular site localities and have precluded the longterm study of contiguous blocks useful for developing models of prehistoric settlement.

In retrospect, a survey design of differential intensity stratified by environmental criteria determined sensitive in the present study might have significantly improved research efficiency. However, without the availability of the present data base, it is unlikely that survey planning would have revolved around environmental variables such as specific elevations and total drainage length by quarter section. More probably, a sampling design would have involved more traditional subdivisions of the baja landscape and results obscuring the upland/lowland settlement dochotomy would have been obtained (cf. Westfall 1978; McCarthy 1982).

Furthermore, the applicability of findings in this study to prediction in immediately adjacent and environmentally similar areas is difficult to assess. A large Classic period platform mound complex has been identified three miles north of the Tucson Basin study area boundary. Recent reconnaissance level surveys between the 2200 and 2700 ft. contour interval demonstrate intense residential and agricultural utilization of this zone during the time of platform mound occupation. Previous sampling surveys (Westfall 1978; McCarthy 1982) in the region failed to identify both the platform mound site and the surrounding band of high site density on the mid-bajada.

## RESULTS

Paul R. Fish, Peter J. Pilles, and Fred Plog


### SUMMARY

Six archeological survey project areas within the Southwestern United States were used as a pilot study to investigate the feasibility of developing predictive models of prehistoric land use (Table 8). Results from all project areas suggest directions for future, more intensive study. Determinants of site location defined were soil types, drainage width, topography, elevation, and site aspect. All settlement distributions involved horticultural populations and sensitive environmental variables could be interpreted to be factors in an agricultural strategy.

In the Tonto study area, topography was found to be the single most important environmental variable. On the Cuba District and Manti-LaSal project areas, site locations were highly related to north and southfacing ridge tops on the edges of desirable agricultural land, possibly to conserve a limited natural resource: farmland. The Jemez District study found that a high correlation existed between terrestrial ecosystems and site clusters. It is worth noting, that the Jemez District study was one of two project areas for which detailed terrestrial ecosystem data were available. Elevation, possibly related to temperature inversions, and drainage widths reflecting degree of stream entrenchment, proved to be good predictors of site distributions in the Tucson Basin. On the Kaibab an evaluation was made of an alternative approach to predictive modeling which was found not useful.

Effectiveness of individual variables differed considerably between study areas. Soils were not important in the Tucson Basin study. It was not possible to evaluate soils in other areas because of a lack of information. Likewise, vegetation was not significant in the Manti-LaSal, Tonto or Kaibab project areas. Proximity to water, generally assumed to be critical throughout the Southwest was not a useful predictor. The only instance where proximity to water was a sensitive indicator was in a small portion of the Manti-LaSal area.

There is considerable variation in the sensitivity of individual variables across the study areas. Furthermore, in many instances, cultural factors played a major role in the distribution and density of site types. The site relationships suggested by these studies must be considered at this time specific to the individual localities examined. These relationships provide ideas and directions for future testing of predictive models.

In evaluating the results from the data bases, it is apparent that predictions with greatest utility for designing survey strategies and the management of cultural resources will be zonal in character. A number of considerations must be given to the design of additional study areas in order to develop the most useful models. For example, study areas need to be of sufficient size to provide culturally meaningful units for analysis and comparison. Likewise, care should be taken to ensure that samples are adequate representations of the cultural systems under examination, or specific portions of these systems. The diversity of environmental variables found useful during this conference demonstrate the need for future studies to remain open

Table 8. Summary of Study Areas.

| PROJECT | CULTURES REPRESENTED | TIME RANGE | STUDY AREA ACREAGE | NO. OF SITES | TOTAL SITE AREA | % SITES FOUND IN A % OF STUDY AREA | % STUDY AREA COVERED BY SITES |
|---|---|---|---|---|---|---|---|
| Study 1 - Kaibab N.F. | | | | | | | |
| Tusayan Ranger District Timber Sales | Archaic and Cohonina | 2,000 B.C. -A.D. 1200 | 11,167 | 187 | 787,997 $m^2$ (190 acres) | --- | 1.7% |
| Study 2 - Tonto N.F. | | | | | | | |
| Cave Creek Ranger District New River Area | Hohokam | A.D. 800-1150 | 2,728 | 87 | 364,545 $m^2$ (88 acres) | 94% sites in 60% of study area | 3% |
| Study 4 - Santa Fe N.F. | | | | | | | |
| Cuba Ranger District Boot Jack Timber Sale | Gallina | A.D. 1150-1275 | 8,464 | 142 | 135,946 $m^2$ (33 acres) | 96% sites in 23% of study area | 0.4% |
| Study 5 - Manti-LaSal N.F. | | | | | | | |
| Monticello Ranger District Allen Canyon | Anasazi | A.D. 875-1250 | 1,580 | 162 | 26,024 $m^2$ (6 acres) | 95% sites in 53% of study area | 0.4% |
| Study 6 - Santa Fe N.F. | | | | | | | |
| Jemez Ranger District Boreggo Mesa | Proto-Jemez | A.D. 1300-1600 | 3,758 | 167 | 258,796 $m^2$ (62 acres) | 88% sites of 33% of study area | 2% |
| Study 7 - Coronado N.F. | | | | | | | |
| Tucson Basin | Hohokam | A.D. 900-1450 | 5,760 | 50 | 2,226,280 $m^2$ (536 acres) | 98% sites in 43% of study area | 9% |

with regard to the selection and identification of environmental variables examined.

## ENVIRONMENTAL AND ARCHEOLOGICAL DATA IMPROVEMENT NEEDS

One of the purposes of this conference was to determine the types of information needed in order to develop a variety of predictive models that can be applied to archeological site information. In analyzing the study areas selected for the pilot project, other needs to improve available environmental and archeological site information have been identified. The availability of specific environmental information is of major importance in the selection and analysis of additional study areas. To ensure a full range of environmental variables can be considered during the modeling process, additional environmental information needs to be collected for use by the modeling group.

Considerable information has been collected on soils, vegetation, watershed, and other types of environmental data by the U.S. Forest Service, Soil Conservation Service, Bureau of Land Management, and other resource management agencies. The availability of such information, both published and unpublished, needs to be determined and a library of environmental information pertinent to the Southwest assembled. As study areas are identified, environmental information for them should be digitized for greater ease of analytical manipulation and comparison.

Much of this information has been collected and catalogued for specific resource management needs and may require some recombination or collapsing of data into analysis units that are more specific for archeological application. In the case of soils, for example, many distinctions are based on characteristics such as particle size that have little utility for archeological purposes.

Over the last ten years, thousands of archeological sites have been inventoried on the Forests of the Southwestern Region. Much of this data base has been collected in manual file systems and has not been computerized. Other site data have been computerized but have not been examined to determine if site information is correct and consistently coded, or edited to ensure they are free of errors. Completion and editing of the Region's computerized cultural resources data bank is necessary in order to select new study areas and to test the variety of models that will be developed in the future. Digitizing site data is also desirable to further facilitate data comparison.

During the analysis of the study areas selected for the conference, problems with some of the data bases were recognized that need to be corrected. Certain types of site information, such as site aspect and site size, have not always been collected, or have not been collected consistently. Such information cannot be determined from maps and return trips to the sites must be made to collect this data. In other cases, such as that of the Kaibab and Santa Fe National Forest studies, gaps exist in areas that were surveyed and new field work is needed to complete the archeological survey for these units. In other studies, such as that for the Cuba District of the Santa Fe National Forest, there is a question as to the comparability of site definitions and site densities identified by various survey crews. Field inspections and sample testing of these areas are necessary to validate data comparability.

Consideration should also be given during future field data collecting stages to determine if changes are needed in the pre-

sent computerized site forms to refine and improve data categories. Refinements in such areas as archeological site and environmental characteristics may be desirable to more accurately characterize the diversity of site types represented in the Southwest.

## RECOMMENDATIONS FOR FURTHER EVALUATION OF THE MODELS

The discussion in this section assumes that issues identified in the preceding two have been addressed, that relatively cleaner environmental and cultural data sets exist. The focus of the discussion will be steps that will help in evaluating the utility of models developed thus far, in improving these models and in developing models for new areas.

### Management Decisions

During the conference several of use learned for the first time that management is apparently in the process of making decisions to not manage specific classes of resources. At least on the Kaibab Naional Forest, lithic scatters are no longer being recorded as a part of surveys of timber areas. It is imperative that individuals constructing preditive models be made aware of all such decisions. While we are concerned about the nature and quality of justifications for such decisions, it is apparent that there may be classes of cultural resources that are ubiquitous in particular areas or that are not impacted by managment undertakings. However, there is no point in undertaking analyses directed toward the generation of predictive models for such classes of sites if there is no intent to manage them.

## ANALYTICAL ROUTINES

At the conference, the majority of our effort was directed toward the construction of zonal models, models that differentiate zones likely to contain sites from those not likely to contain sites. We lacked the computer software that would have been required to test point specific models. Given that site area is never more than 9% of project area for any of our studies, there is a continuing need to attempt to evaluate point specific models. We are not confident that it will ever be possible to develop such models, but a test is warranted. Specificially, we require software that will assign sites to monothetic sets on the basis of the characteristics of the point at which they are located and simultaneously calculate the portion of a project area that shares the characteristics of each of the sets. Only with such software will it be possible to construct and test point specific models.

## EVALUATING THE MODELS

In order to determine how well the models developed at this conference perform, it will be necessary to acquire a number of additional data sets.

(1) Contiguous survey areas. A cost effective approach to testing the models requires the continued use of data sets that have already been generated. The study areas utilized were selected because they were the largest that we could obtain. There may be nearby contiguous areas that are not quite as large. If so, these data would be ideal for the initial testing of models.

(2) All survey data from relevant portions of the forests under study. A second level of testing can occur using information from

all of the projects conducted in portions of the forests for which the models would appear to be relevant, however small those projects. Ultimately, the models must be demonstrated to have utility for small as well as large project areas.

(3) Data describing areas in which no sites were found during survey. It is necessary for any modeling effort to begin with data describing the locations of sites. Eventually, information on areas in which sites were not found also becomes useful. These can be used to determine if the models successfully predicted that the areas in question would prove to be devoid of archeological sites.

(4) New survey projects. Additional survey is the least cost effective means of testing. However, in some areas it may prove to be the only means of evaluating the models. In most instances an initial test can be done using a sampling strategy. However, to validate the effectiveness of the model additional work may be required. An initial sample can easily show that a model does not work. However, if the model appears to work on the basis of an initial sample, this result needs to be confirmed. Depending on the circumstances, additional sampling or reconnaissance may suffice. In others, inventory survey of at least some portions of an area may be required.

# CONCLUSIONS

Linda S. Cordell, Jeffrey S. Dean, and Joseph A. Tainter

## SUMMARY

Many discussions of preditive modeling including the present volume, contrast inductive versus deductive approaches. Inductive approaches are characterized, as those that move from a known universe (drainage, river valley, etc.) to some unknown but usually neighboring area. Site densities, site types, etc. found in the first area are then predicted for the second area. Not surprisingly, such inductive modeling efforts are frequently successful in predicting relative numbers of sites and frequencies of site types. However, under such an approach the investigator may not know why a particular pattern is repeated from one area to another. When the model fails to predict, there is no basis for understanding why.

Deductive models, on the other hand, may be generated on the basis of theoretical considerations of human behavior. They are explanatory in nature, so that axiomatically one has some understanding of why a predictive model does or does not work. Such models may be criticized because of their abstract nature. Purely deductive models are developed independent of empirical patterns. They may produce results that in the short term are less useful than inductive models, but that in the long run have the potential for far greater applicability. In fact, the most profitable method is to integrate the two approaches, as any credible model must ultimately do.

This conference began with the assignment of tasks along the dichotomous lines suggested above. Green, DeBloois, Fish, Pilles, Plog, and Ravesloot undertook the "modeling" task from the inductive perspective. Tainter, Dean, Cordell, and Upham were assigned the role of "developing theory." In fact, this volume, and the summary statements made here, suggest that there is a close relationship between inductive and deductive modeling efforts, between "reality" and "theory."

The articulation between modeling and theory development may in part be explained by the fact that all of us are working with the archeological record of the Southwest, an area in which we have worked for many years. We carry with us notions of the kinds of sites we know about and the kinds of settings they are located in. Further, the efforts, over the past ten years, of the Southwestern Anthropological Research Group (Gumerman 1971, 1972; Euler and Gumerman 1978) have conditioned most of use into thinking about the locations of sites with respect to various kinds of environmental variables. A brief summary of the activities of the two conference "moieties" reflects some of the similarities and differences in our thinking.

## MODELING RESULTS

The data base studies focused on the correlations between environmental variables and settlement locations and distributions. In all instances, environmental characteristics considered were adapted from those identified by the Southwestern Anthropological Reserarch Group (Gumerman 1971, 1972; Euler and Gumerman 1978), and include vegetation, topography, soil, drainage type, aspect, average slope, elevation,

arable land, and nearest water source. All of the above variables, when such information was available were considered as possible determinants of settlement locations and correlations were inductively sought. Whenever possible, cultural factors were considered.

Perhaps one of the most encouraging initial observations of the modeling group was the degree to which sites were found to cluster within each of the survey areas and the relatively small amount of land found to contain archeological sites. In fact, it must be remembered that in virtually all the cases, the sites involved represented habitation sites, or other relatively obtrusive occurrences such as large fields systems in the Tucson Basin.

## THEORY RESULTS

The discussion of theory relevant to agriculturalists in the Southwest, made a point of indicating that there is a high diversity in the kinds of settings in which agriculture can be practiced. The diversity is, in part, reflected in the criteria that the modeling group found useful in predicting site locations. Thus, arable land figured as an important indicator in each of the case studies, although the character of the arable land was variously defined. In the Tucson Basin study, settlement was found to correlate well with elevation, which underlies temperature, the presence of water, and possibly riparian vegetation. In the Jemez area, arable land was defined using the terrestrial ecosystem land classes developed by the Forest Service. In the Allen Canyon case, arable land was found to predominate within the drainages. In the New River study, sites correlated with colluvial slopes, and in the Cuba district, sites were found to locate on ridges, presumably adjacent to arable land, but in situations that precluded pithouse flooding. As all conference participants noted, the need to develop criteria for point distributions of sites is one of the next most critical steps. These preliminary results suggest that this endeavor will entail development of specific criteria for different areas, and will be considerably aided by prior random plot simulations of distributions with respect to classes of arable land and available surface water.

Although various definitions of arable land were important to each of the modeling efforts, the relationship between sites and arable land differed. As anticipated by the discussion of settlement among agriculturalists, it appears as though population density greatly modifies the relationship between settlements and physical characterisitics of the landscape. For example, in the Allen Canyon study, sites seem to have been located on arable land, whereas in the Jemez case study, with a much higher density, sites are located adjacent to but decidely off agricultural land.

One of the major points of the discussion of agriculture, in general, was the notion that sustaining areas and resourceextraction areas continued to be of critical importance throughout the prehistory of the Southwest. In all of the case study material, sites located in areas where they were not predicted to occur were "redundant" of sites in predicted areas. The first category of sites consisted primarily of lithic scatters, sherd and lithic scatters, pot breaks and small sites that probably relate to extraction activities rather than habitation. This, again brings up the important point that we need to know much more about the location of "low visibility" activities. It is to be hoped that some of the information in the discussions of foraging activities (Tainter this volume) and of resource distribution (Dean

this volume) will permit this to be incorporated in future endeavors.

It is notable that none of the data bases used during the conference were ideally suited for evaluating forager land uses. Where information on low density scatters (which result from foraging activities) was recorded in the data bases the conference analysists did not separate these for studies of sufficient intensity. And in one case, the field archeologist chose not to even record such manifestations, after it became apparent that many of them were present in the area. This is most regrettable, given the importance of such sites in understanding not only the adaptive strategies of hunting and gathering peoples, but also the overall subsistence strategies of those who practiced agriculture.

The present case studies can neither serve to illustrate the application of foraging theory, nor help to evaluate that theory. It therefore seems clear that other data sets must be acquired for this purpose, data sets that reflect an unbiased picture of the true distribution of archeological remains through all elevation zones. One such data set has been identified on the Cibola National Forest that is suitable for this purpose, while others will be sought.

In the Allen Canyon study, it was observed that one canyon which was slightly less desirable for agricultural activities was used more often in a logistical manner, presumably by agriculturalists settled nearby. This has clear implications regarding foraging strategies and the use of space by agriculturalists. Viewed in terms of Optimal Foraging Theory, a situation in which there is an expectation of a large number of feeding visits to a location (in this case, the agricultural field qualifies as environmental "patch" that is sufficiently productive to permit nearby residence) selects for reduction in commuting and transport costs. This will result in foraging near the base settlement (to the extent that the environment permits it), even when this results in increased search costs due to overlap in search areas. The many foraging locations in the general location of agricultural settlements is expectable, and should be anticipated when developing predictive models. To some degree, the archeological scatters briefly mentioned in the Jemez study may reflect a similar situation.

## MODEL-THEORY ARTICULATION

Consideration of the individual studies reveals that different environmental variables were effective predictors in different cases, at least in regard to the behavior of agriculturalists. It is not clear that a prior determination of these differing relationships could be made to structure predictions in each area, even though site distributions were highly aggregated in most cases. Do these results signify that there is no articulation between the environmental variables to predict site occurrences? Probably not. None of these empirical test results contradict relationships specified by the provisional theoretical model. Two factors may be involved here: first, the present level of theoretical development is most likely not sufficiently precise, and second the non-congruence problem probably identifies major disjunctions between the resource distributions that influenced prehistoric populations to locate activities in particular places and the modern environmental variables archeologists use to represent these resource distributions.

In order to understand these disjunctions, more research on relationships between potentially exploitable resources and potential surrogate indicators of these

resources is vital, along with research on the natural and human caused transformations that have altered the environments of the target areas since the sites were produced. The lack of a close correspondence between theory and the model building results, increases rather than decreases the need for a strong theoretical component in the predictive modelling process. Such a theory provides the only mechanism for comprehending the complex interactions among human behavior and environmental variability and for understanding how attributes of the modern environment can be used as indicators of past environmental variables that influenced prehistoric activity locating behavior. There is a sense in which the participants in a conference of this sort must address the question of what we have learned that is new, that changes the way in which we think about our data, or the way we hope to do it better next time. With respect to learning something new, few of us were surprised that the modeling efforts show that the locations of sites pattern strongly with respect to a few environmental variables. Most experienced archeologists can tell you where the sites areor at least the big sites. But, such information is neither trivial nor fully satisfactory. As all participants agreed, the locations of sites not only differ markedly from one area to the next, but we still need a great deal of information to determine why some areas contain few or no sites. Further, all the participants agree that understanding the more ephemeral occurrences is critically important to our interpretations of prehistoric land use, settlement changes, and cultural development. These are, of course, the most difficult locations to predict.

Finally, we are aware that although none of the study cases we selected were ideal from all perspectives, the situations we selected to examine approximate those facing land management on a day to day basis. We must, as a next step examine the effectiveness of predictive models, informed by theory, for very large areas, such as entire forests, and we must address the issue of developing predictive models for non-contiguous areas of land. All of us felt that in most respects the cases we examined were too small to represent the entire settlement/ subsistence areas of the groups which inhabited them. We need to examine the more realistic catchement areas, and again in light of theory, develop models that bear some resemblance to the probable use areas of real prehistoric groups.

In sum, predictive modeling is not an evil that has befallen archeologists in management situations. Rather, it provides an unprecedented opportunity to evaluate what we know, or think we know, and to refine our skills at explaining the nature of the data base that we hold most dear.

# RECOMMENDATIONS

Evan I. DeBloois, Dee F. Green, and Steadman Upham

## SUMMARY

It was clear from the outset of this project that many if not all of the data sets selected were fraught with problems. Considering the amount of thought that went into the selection of the best available survey information for analysis, one wonders in what condition other survey data sets will be found. In spite of the difficulties encountered with the data, we have learned a great deal about the future direction this effort should take and some of the decisions that must be made if we are to achieve success.

One of the most obvious problems facing the development and implementatin of survey refinement strategies lies with the uneven quality of the data being collected in current surveys. These problems take three major forms:

1. Data on environmental characteristics of survey areas are frequently lacking, or is available only for site locations. Information on soils, soil moisture, forage potential, and other natural resources and their distribution across the landscape is of critical importance in determining associations between these resources and site locations. In particular with horticultural systems, these environmental features are necessary for accurate association of sites with environmental variables. In addition, the Forest Service presently maintains large files of relatively precise environmental information. These data need to be made available to archeologists and cultural resource managers.

One of the most critical problems that archeologists face in attempting to predict the location of archeological sites is to determine the extent of change in environmental conditions that have taken place from some baseline date in the past. Dean (this volume) has provided an extensive outline of environmental characteristics and has discussed the ways and rates in which they have changed in the past. Similarly, the summaries that follow the sections on theory and the study cases, have provided a relatively detailed list of environmental information that needs to be acquired. Where possible, the Forest Service should implement data collection strategies to obtain these necessary environmental data. It may be possible, in some cases, to acquire this information in conjunction with such activities as timber, range of wildlife projects.

In addition to this kind of general environmental information, it is becoming increasingly necessary to develop a body of more specific data that is suitable for evaluating the environmental characteristics of archeological site locations. In many instances, archeologists are able to specify the distance from water, stands of potential fuel wood or construction timbers, or other resources from which an archeological site is located. There is, however, little data available to evaluate how the locations of past human activity differ from areas that were not utilized. Again, the Forest Service can undertake data collection and analysis independently or in conjunction with other projects to address this important issue.

2. Many data sets suffer from a lack of definement and systematic coverage. Boundaries between areas surveyed and unsurveyed are often not drawn. This makes analysis of site distributions difficult. If areas not containing sites are actually areas not surveyed, associations will not be viable. Some data sets suffer from unsystematic survey coverage. Areas within the survey boundaries were left unsurveyed for a variety of reasons. This has resulted in areas with no site information; areas that frequently coorelate with different environmental zones. Similarly, the Forest Service site form is presently inadequate for many of the specific needs of predictive modeling. The form needs to be modified to accomoodate the new data requirements, particularly with respect to environmental information, that are essential to refining survey strategies.

3. Another problem encountered is the variability in definitions utilized from survey to survey. Some cases exclude lithic scatters from recording, others include them. Some studies include isolated artifact locations, others ignore them. Some use wide crew spacing, others use closely spaced coverage. Each of these definitional and methodological problems and variances results in an increase in the uncontrollable bias built into the data set and in increased likelihood that efforts at analysis will fail.

## Recommendation

If success is to be achieved with survey refinement approaches, we must review and strengthen the minimum standards for survey. These standards must address:

1. Clear definition of survey boundaries and techniques employed.

2. Minimum coverage and recording standards for surveys and cultural features located.

3. Required computerization of data and reporting of results of surveys.

4. Collection and analysis of critical environmental data, i.e., soils, vegetation, geological features, water, and other natural resources.

5. Regular review of survey results and analysis of data provided in view of survey refinement techniques.

The potential for refining and implementing survey techniques is clearly demonstrated by the high degree of clustering exhibited by most of the study areas. This permitted the potential discovery of the majority of sites by the survey of less than one half of the area. The analysis of most of the areas showed sites clustered into locations with many empty acres in between. Most of the effort at analysis was directed at identifying environmental coorelates with this patterning.

It was also clear that different environmental characteristics were coorelated with patterning in different study areas and in some cases, in the same area. Even though this suggests the unlikelihood of developing widely applicable survey refinement strategies, it remains clear that there is great potential utility in pursuing locally applicable templates of site location.

The next step to be taken is the application of the information gained in this project to other areas of the same Forest or Region and to explore the viability of the environmental corelates identified to continue to predict site patterning. Additional data sets need to be examined in a similar manner and some of the same data

sets could yield more information with additional environmental data collection.

The potential for success is high with this effort. The refinement of survey techniques will not only have an immediate payoff in the potential reduction of survey costs, it will also provide comparative data for resource planning efforts now underway. It appears likely that the implementation of procedures to analysize survey data and examine the coorelation of environmental variables with site patterning will also be sufficient to meet legal requirement of the NHPA and provide the basis for compliance with Section 106 requirements at the Forest planning level.

By integrating this process into Forest management activities, it should be possible to design survey techniques that would focus on areas with high potential and reduce the sampling fraction on areas with low potential. It is important, however, due to the tendency for coorelation patterns to vary with specific local conditions, that a constant process of reevaluation of survey strategies be carried out as well.

It also appears clear that the task of developing the initial coorelation models will be a major task if left to individual Forests. The pressures of day-to-day business keep most Forest archeologist occupied. The burden of assemblying the technical data requirements, preparing and executing the computerized analytical aids necessary, and analysizing the variables present may result in the job not being accomplished on most Forests.

## ALTERNATIVES

The range of alternatives at this point in the evaluation of survey refinement strategies is wide. One can continue, stop, speed up, or slow down the process. One can structure the approach nationally, regionally, or locally. As one assesses the current political climate, it appears clear that ways to reduce costs or increase production (i.e., efficiency) or both are at a premium. The potential of accomplishing one or more of these goals by the process of refining survey strategies is very high. The risks are, however, not minor.

The science of predicting the location of past human activities is at best imprecise. Inadequate models of prehistoric site clustering or erroneous coorelations of sites with environmental variables could be disastrous to large numbers of irreplaceable cultural resources.

On the other side, however, is the potential of reducing unit costs for most survey projects by 25 to 40% over current procedures while at the same time inputting greatly increased and improved cultural resource data into the land management planning process. Developing testable and verifiable models of site locations based upon environmental factors would greatly facilitate the project planning and decisionmaking process.

From the work performed at this conference, it would appear that survey refinement strategies are emminently possible and that increasing numbers of archeologists both in the Forest Service and in academic communities are developing the necessary procedures and theoretical underpinning.

### Alternative One

Continue with the present procedures. The current economic climate makes meeting legal requirements difficult and costly. Most Regions and Forests are experiencing difficulty in meeting the requirements of survey on all terrain-altering projects.

Most managers have recognized the need for another approach that is more cost effective. This alternative is not considered a viable option given these conditions.

## Alternative Two

Develop methods for refining survey methods through the analysis of cultural resource distributions and environmental corelations. The results of this volume demonstrate the potential of this alternative. There are, however, several options to consider for implementing this alternative.

### Option 1

The Core Team Approach. As outlined in the discussion of future needs, there are several tasks that need to be performed in order to implement the process of survey refinement. This option approaches the task on a national basis by forming a core team of individuals to provide direction and technical assistance to the Regions in the development of analytic methods, standards and guidelines for model building and testing. Because of the highly technical nature of this activity and the amount of time required to carry it out, it is impossible to expect speedy results by making this another task of existing WO, RO or Forest specialists. A small team, devoted to the project, will have a much greater potential for success at a much reduced time frame than any other option considered.

### Option 2

The Regional Approach. This option differs from Option 1 in that each Region is given primary responsibility for developing and implementing the procedures. A team would be assembled in each Region to provide direction and technical support to the Forests. The disadvantages of this approach are the higher initial costs for funding nine separate teams of specialists and the higher annual costs on initial implementation. Another factor to consider is the size of Regional programs. For several Regions this team approach would mean doubling the current levels of staff and funding for several years. The advantage of this approach, if implemented, would be the speed at which full implementation could be achieved.

### Option 3

The Forest Approach. This approach differs in the placing of the work load at the Forest level. WO and RO responsibilities would be limited to the preparation of guidelines and standards for the activity. Forest teams of specialists could much more rapidly develop working models for survey refinement but the costs would be extremely high. Other disadvantages are the likelihood of considerable variability in the methods developed. Considerable effort would have to be expended by the Region and WO to keep the project from flying apart and to assure that methods are reasonable and valid. Of the three options, this is the least likely to succeed because of the pressures of other competing activities.

It is recommended that Alternative Two, Option 1, be selected as the preferred method of implementing the process of refining survey methods in the Forest Service.

## STAFFING NEEDS

Alternative 1 - Core Team

Ft. Collins Base

Staff - full time
- 1 GS 14 Archeologist - team leader
- 1 GS 11 Geometronic specialist/programmer
- 1 GS 4 Clerk

Equipment
- 1 dedicated terminal tied to test region(s)

Travel
Consultants

Test Region Base

Staff - full time
- 1 GS 12 project liason*
- 1 GS 9 Archeologist - field coordinator
- 1 GS 4 Clerk

Staff - part time
- 1 GS 7 Archeologist - field supervisor
- 1 GS 5 Archeological Technician
- 2 GS 4 Archeological Technicians

Equipment
- 1 dedicated terminal tied to Ft. Collins and RO FLIPS
- 1 4x4 crew cab pickup

Travel
Consultants

*This person would be a member of the Core team but stationed in the test Region(s)

Alternative 2 - Regional Teams

Region Base (needs per region)

Staff - full time
- 1 GS 12 Archeologist - team leader
- 1 GS 11 Geometronics specialist/programmer
- 1 GS 9 Archeologist - project liason

Equipment
- 1 dedicated terminal tied to Ft. Collins and FLIPS

Travel
Consultants

Forest Based (recommend 2 forest per region)

Staff - full time
  1 GS 9 Archeologist - field coordinator
Staff - part time
  1 GS 7 Archeologist - field supervisor
  1 GS 5 Archeological Technician
  2 GS 4 Archeological Technicians
Equipment
  1 dedicated terminal tied to Ft. Collins and RO FLIPS
  1 4x4 crew cab pickup
Travel
Consultants

Alternative 3 - Forest Teams

Forest Based

Staff - full time
  1 GS 11 Archeologist - team leader (Forest Archeologist should be promoted to GS 12 and have overall responsibility)
  1 GS 9 Geometronics specialist/programmer
  1 GS 9 Archeologist - field coordinator
  1 GS 4 Clerk

Staff - part time
  1 GS 7 Archeologist - field supervisor
  1 GS 5 Archeological Technician
  2 GS 4 Archeological Technician
Equipment
  1 dedicated terminal tied to Ft. Collins and FLIPS
  1 4x4 crew cabl pickup
Travel
Consultants

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